

ANATOMY

DESCRIPTIVE AND APPLIED

BY

HENRY GRAY, F.R.S., F.R.C.S.

FORMERLY LECTURER IN ANATOMY AT ST. GEORGE'S HOSPITAL MEDICAL SCHOOL.

TWENTIETH EDITION

EDITED BY

ROBERT HOWDEN

M.A., D.Sc., M.B., C.M.

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF DURHAM

NOTES ON APPLIED ANATOMY

REVISED BY

A. J. JEX-BLAKE, M.A., M.D.Oxon., F.R.C.P.Lond.

SENIOR ASSISTANT PHYSICIAN TO ST. GEORGE'S HOSPITAL

AND

W. FEDDE FEDDEN, M.B., M.S.Lond., F.R.C.S.

PROFESSOR AND LECTURER ON SURGERY, ST. GEORGE'S HOSPITAL

*WITH 1168 ILLUSTRATIONS
OF WHICH 520 ARE COLOURED*

LONGMANS, GREEN AND CO.

39 PATERNOSTER ROW, LONDON

FOURTH AVENUE & 30TH STREET, NEW YORK

BOMBAY, CALCUTTA, AND MADRAS.

1918

BIBLIOGRAPHY

<i>First</i>	<i>Edition</i>	1858	By HENRY GRAY, F.R.S., F.R.C.S. <i>St. George's Hospital.</i>
<i>Second</i>	"	1860	
<i>Third</i>	"	1863	By TIMOTHY HOLMES, M.A., F.R.C.S., <i>St. George's Hospital.</i>
<i>Fourth</i>	"	1865	
<i>Fifth</i>	"	1869	
<i>Sixth</i>	"	1872	
<i>Seventh</i>	"	1875	
<i>Eighth</i>	"	1877	
<i>Ninth</i>	"	1880	By T. PICKERING PICK, F.R.C.S., <i>St. George's Hospital</i>
<i>Tenth</i>	"	1884	
<i>Eleventh</i>	"	1887	
<i>Twelfth</i>	"	1890	
<i>Thirteenth</i>	"	1892	
<i>Fourteenth</i>	"	1897	By T. PICKERING PICK Prof. R. HOWDEN <i>University of Durham</i>
<i>Fifteenth</i>	"	1901	
<i>Sixteenth</i>	"	1905	By Prof. R. HOWDEN, <i>University of Durham.</i>
<i>Seventeenth</i>	"	1909	
<i>Eighteenth</i>	"	1913	
<i>Nineteenth</i>	"	1916	
<i>Twentieth</i>	"	1918	

THE FIRST EDITION OF THIS WORK

WAS DEDICATED TO

SIR BENJAMIN COLLINS BRODIE, BART.

F.R.S., D.C.L.

IN ADMIRATION OF HIS GREAT TALENTS AND IN REMEMBRANCE
OF MANY ACTS OF KINDNESS SHOWN TO THE ORIGINAL
AUTHOR OF THE BOOK FROM AN EARLY PERIOD
OF HIS PROFESSIONAL CAREER

PREFACE

TO

THE TWENTIETH EDITION

THE call for a new edition in a little over eighteen months is proof of the increasing usefulness and popularity of Gray's *Anatomy*.

In this edition, as in the eighteenth and nineteenth, the new or 'Basle' terminology (or an English translation of it) is used, and where a new name differs materially from an old one, the latter is placed within brackets after the former. Both sets of names are indexed.

I tender my best thanks to Dr. J. Acworth Menzies, Professor of Physiology, and to Dr. E. Philip Stibbe, Demonstrator of Anatomy, in this University. Professor Menzies has kindly corrected the histological part of the book, while Dr. Stibbe has helped to revise the text and pass the volume through the press.

The drawings for the new illustrations (about sixty in number) were made by that skilled and painstaking artist, Mr. Sydney A. Sewell.

ROBERT HOWDEN.

UNIVERSITY OF DURHAM COLLEGE OF MEDICINE,
NEWCASTLE-UPON-TYNE, *February*, 1918.

HENRY GRAY, F.R.S., F.R.C.S.

THE readers of Gray's *Anatomy*, the first edition of which was published sixty years ago, may be interested to learn something of its author, Henry Gray. The following information regarding his career has been extracted from an article which appeared in the *St. George's Hospital Gazette* of May 21st, 1908.

Gray, whose father was private messenger to George IV. and also to William IV., was born in 1827, but of his childhood and early education nothing is known.

On the 6th of May, 1845, he entered as a perpetual student at St. George's Hospital, London, and he is described by those who knew him as "a most painstaking and methodical worker, and one who learnt his anatomy by the slow but invaluable method of making dissections for himself."

While still a student he secured, in 1848, the triennial prize of the Royal College of Surgeons for an essay entitled, "The origin, connexions and distribution of the nerves to the human eye and its appendages, illustrated by comparative dissections of the eye in other vertebrate animals."

At the early age of twenty-five he was, in 1852, elected a Fellow of the Royal Society, and in the following year he obtained the Astley Cooper prize of three hundred guineas for a dissertation "On the structure and use of the spleen."

He held successively the posts of demonstrator of anatomy, curator of the museum and lecturer on anatomy at St. George's Hospital, and was in 1861 a candidate for the post of assistant-surgeon. Unfortunately he was struck down by an attack of confluent smallpox, which he contracted while looking after a nephew who was suffering from that disease, and died at the early age of thirty-four. A career of great promise was thus untimely cut short. Writing on June 15th, 1861, Sir Benjamin Brodie said, "His death, just as he was on the point of obtaining the reward of his labours . . . is a great loss to the Hospital and School."

In 1858 Gray published the first edition of his *Anatomy* which covered 750 pages and contained 363 figures. He had the good fortune to secure the help of his friend, Dr. H. Vandyke Carter, a skilled draughtsman and formerly a demonstrator of anatomy at St. George's Hospital. Carter made the drawings from which the engravings were executed, and the success of the book was, in the first instance, undoubtedly due in no small measure to the excellence of its illustrations. A second edition was prepared by Gray and published in 1860.

The portrait here given of Gray is a reproduction of one which appeared in the *St. George's Hospital Gazette* of May 21st, 1908, where the original is described as being "a very faded photograph taken by Mr. Henry Pollock, second son of the late Lord Chief Baron, Sir Frederick Pollock, and one of the earliest members of the photographic society of London".



Henry Gray

CONTENTS

	PAGE	The vertebral column (<i>continued</i>)	PAGE
INTRODUCTION	XV	The coccyx	176
HISTOLOGY		Vertebral column as a whole	179
The animal cell	1	The sternum	182
Epithelium	4	The ribs	185
Connective tissues	7	The costal cartilages	189
The connective tissues proper	7	The thorax	190
Cartilage	14	The skull	193
Bone	17	Cranial bones	193
The circulating fluids	26	The occipital bone	193
Blood	26	The sphenoidal bone	197
Lymph	29	The temporal bones	203
Muscular tissue	30	The parietal bones	211
Nervous tissue	34	The frontal bone	213
EMBRYOLOGY		The ethmoidal bone	217
Introductory remarks	41	The inferior nasal concha	220
The ovum	41	The lacrimal bones	220
Coverings of the ovum	42	The nasal bones	221
Maturation of the ovum	43	The vomer	222
The spermatozoon	44	Sutural or Wormian bones	224
Fertilisation of the ovum	47	Facial bones	224
Segmentation of the fertilised ovum	48	The maxillæ	224
The neural groove and tube	53	The palatine bones	230
The notochord	54	The zygomatic bones	233
The primitive segments	55	The mandible	235
Formation of the embryo	55	The hyoid bone	240
The yolk-sac	57	Exterior of the skull	241
The fetal membranes and placenta	59	Norma verticalis	241
Development of the parietes	69	Norma basalis	241
Development of the nervous system and sense organs	85	Norma lateralis	244
Development of the vascular system	109	Norma occipitalis	247
Development of the digestive and respiratory apparatus	128	Norma frontalis	248
Development of the body-cavities	143	Interior of the skull	252
Development of the urinary and generative organs	145	Inner surface of the skull-cap	252
The form of the embryo at different stages of its growth	156	Upper surface of base of the skull	252
OSTEOLOGY		The nasal cavities	256
General description of bones	160	Differences in the skull due to age	258
The vertebral column	161	Sexual differences in the skull	259
General characteristics of a vertebra	161	Craniology	260
Cervical vertebra	162	The extremities	265
Thoracic vertebra	167	Bones of the superior extremity	266
Lumbar vertebra	169	The scapula	266
The sacrum	171	The clavicle	271
		The humerus	274
		The radius	279
		The ulna	283
		The hand	290
		The carpus	290
		The metacarpus	294
		The phalanges	296
		Ossification of the bones of the hand	296
		Bones of the inferior extremity	298
		The hip-bone	298
		The pelvis	305
		The femur	309
		The tibia	318
		The fibula	322
		The patella	324

CONTENTS

	PAGE		PAGE
The foot	325	FASCIAE AND MUSCLES OF THE HEAD	426
The tarsus	325	I. The muscle of the scalp	426
The metatarsus	335	II. Muscles of the eyelids	428
The phalanges	337	III. Muscles of the nose	429
Ossification of the bones of the foot	338	IV. Muscles of the mouth	430
Comparison of the bones of the hand and foot	339	V. Muscles of mastication	432
Sesamoid bones	340		
SYNDESMOLOGY		FASCIAE AND MUSCLES OF THE ANTERO-LATERAL REGION OF THE NECK	435
General description of articulations	342	I. Superficial and lateral cervical muscles	437
Classification of joints	343	II. Supra- and infrahyoid muscles	439
The kinds of movement permitted in joints	345	III. Anterior vertebral muscles	442
Articulation of the mandible	346	IV. Lateral vertebral muscles	444
Articulations of the vertebral column	348		
Articulations of the vertebral column with the cranium	357	FASCIAE AND MUSCLES OF THE TRUNK	444
Costovertebral articulations	358	I. Deep muscles of the back	444
Sternocostal articulations	361	II. Suboccipital muscles	449
Intercostal articulations	363	III. Muscles of the thorax	450
Costochondral articulations	363	Mechanism of respiration	456
Articulation of the manubrium with the body of the sternum	363	IV. Muscles of the abdomen	456
Mechanism of the thorax	363	V. Muscles of the pelvis	467
Articulations of the upper extremity	365	VI. Muscles of the perineum	471
I. Sternoclavicular articulation	365	1. Muscles of the anal region	471
II. Acromioclavicular articulation	367	2. Muscles of the urogenital region :	
Ligaments of the scapula	368	(a) In the male	473
III. Humeral articulation or shoulder-joint	369	(b) In the female	476
IV. Cubital articulation or elbow-joint	373	FASCIAE AND MUSCLES OF THE UPPER EXTREMITY	478
V. Radio-ulnar articulations	376	I. Muscles connecting the upper extremity with the vertebral column	478
VI. Radiocarpal or wrist-joint	380	II. Muscles connecting the upper extremity to the anterior and lateral thoracic walls	481
VII. Intercarpal articulations	382	III. Muscles of the shoulder	485
VIII. Carpometacarpal articulations	385	IV. Muscles of the arm	488
IX. Intermetacarpal articulations	386	V. Muscles of the forearm	491
X. Metacarpophalangeal articulations	386	Volar antibrachial muscles	491
XI. Articulations of the digits	387	Dorsal antibrachial muscles	496
Articulations of the lower extremity	387	VI. Muscles of the hand	500
I. Sacro-iliac articulation	388	Lateral volar muscles	506
II. Pubic symphysis	390	Medial volar muscles	508
Mechanism of the pelvis	391	Intermediate muscles	508
III. Coxal articulation or hip-joint	393		
IV. Knee-joint	399	FASCIAE AND MUSCLES OF THE LOWER EXTREMITY	513
V. Articulations between the tibia and fibula	409	I. Muscles of the iliac region	513
VI. Talocrural articulation or ankle-joint	411	II. Muscles of the thigh	515
VII. Intertarsal articulations	414	1. Anterior femoral muscles	515
VIII. Tarsometatarsal articulations	418	2. Medial femoral muscles	519
IX. Intermetatarsal articulations	418	3. Muscles of gluteal region	522
X. Metatarsophalangeal articulations	420	4. Posterior femoral muscles	526
XI. Articulations of the digits	420	III. Muscles of the leg	528
Arches of the foot	420	1. Anterior crural muscles	528
		2. Posterior crural muscles	529
		3. Lateral crural muscles	534
		Fascia round the ankle	535
		IV. Muscles of the foot	537
		Dorsal muscle	537
		Plantar muscles	537
MYOLOGY			
General description of muscles	423		
Tendons, aponeuroses, and fasciæ	425		

CONTENTS

ANGIOLOGY	PAGE	THE VEINS (<i>continued</i>)	PAGE
Outline of circulation of the blood	545	Veins of the upper extremity and thorax	687
Structure of arteries	546	Superficial veins of upper extremity	687
Structure of capillaries	547	Deep veins of upper extremity	689
Structure of veins	549	Veins of the thorax	691
The thoracic cavity	550	Veins of the vertebral column	694
Pericardium	551	Veins of the lower extremity, abdomen, and pelvis	695
Heart	553	Superficial veins of lower extremity	695
Chief peculiarities in the vascular system of the fetus	566	Deep veins of lower extremity	698
Fetal circulation	566	Veins of abdomen and pelvis	698
Changes in the vascular system at birth	568	Portal system of veins	704
THE ARTERIES (general description of)	569	THE LYMPHATIC SYSTEM	707
Pulmonary artery	569	Lymphatic vessels	707
Aorta	571	Lymph-glands	708
Ascending aorta	571	Thoracic duct	710
Arch of aorta	573	Right lymphatic duct	712
Innominate artery	575	Lymph-glands of the head and neck	713
ARTERIES OF THE HEAD AND NECK	576	Lymphatic vessels of the head and neck	716
Common carotid arteries	576	Lymph-glands of the upper extremity	718
External carotid artery	579	Lymphatic vessels of the upper extremity	721
Triangles of the neck	591	Lymph-glands of the lower extremity	721
Internal carotid artery	594	Lymphatic vessels of the lower extremity	723
Arteries of the brain	601	Lymph-glands of the abdomen and pelvis	724
ARTERIES OF THE UPPER EXTREMITY	602	1. Parietal lymph-glands	724
Subclavian arteries	602	2. Visceral lymph-glands	726
The axilla	612	Lymphatic vessels of the abdomen and pelvis	729
Axillary artery	613	1. Parietal lymphatic vessels	729
Brachial artery	617	2. Visceral lymphatic vessels	730
The cubital fossa	617	(1) Lymphatic vessels of the subdiaphragmatic portion of the digestive tube	730
Radial artery	620	(2) Lymphatic vessels of the spleen and suprarenal glands	732
Ulnar artery	623	(3) Lymphatic vessels of the urinary organs	732
ARTERIES OF THE TRUNK	627	(4) Lymphatic vessels of the reproductive organs	734
Thoracic aorta	627	Lymph-glands of the thorax	735
Abdominal aorta	631	1. Parietal lymph-glands	735
Common iliac arteries	642	2. Visceral lymph-glands	736
Hypogastric artery	644	Lymphatic vessels of the thorax	737
External iliac artery	651	1. Lymphatic vessels of the thoracic wall	737
ARTERIES OF THE LOWER EXTREMITY	653	2. Lymphatic vessels of the thoracic viscera	738
Femoral artery	653	THE VEINS (general description of)	670
Femoral sheath	653	Pulmonary veins	670
Femoral triangle	654	Veins of the heart	671
Adductor canal	655	Veins of the head and neck	672
Popliteal fossa	660	Veins of the exterior of the head and face	672
Popliteal artery	661	Veins of the neck	675
Anterior tibial artery	664	Diploic veins	678
Arteria dorsalis pedis	665	Veins of the brain	679
Posterior tibial artery	666	Venous sinuses of the dura mater	680
Medial plantar artery	668	Emissary veins	686
Lateral plantar artery	668	THE VEINS (<i>continued</i>)	
THE VEINS (general description of)	670	Veins of the upper extremity and thorax	687
Pulmonary veins	670	Superficial veins of upper extremity	687
Veins of the heart	671	Deep veins of upper extremity	689
Veins of the head and neck	672	Veins of the thorax	691
Veins of the exterior of the head and face	672	Veins of the vertebral column	694
Veins of the neck	675	Veins of the lower extremity, abdomen, and pelvis	695
Diploic veins	678	Superficial veins of lower extremity	695
Veins of the brain	679	Deep veins of lower extremity	698
Venous sinuses of the dura mater	680	Veins of abdomen and pelvis	698
Emissary veins	686	Portal system of veins	704
THE LYMPHATIC SYSTEM	707	THE LYMPHATIC SYSTEM	707
Lymphatic vessels	707	Lymphatic vessels	707
Lymph-glands	708	Lymph-glands	708
Thoracic duct	710	Thoracic duct	710
Right lymphatic duct	712	Right lymphatic duct	712
Lymph-glands of the head and neck	713	Lymph-glands of the head and neck	713
Lymphatic vessels of the head and neck	716	Lymphatic vessels of the head and neck	716
Lymph-glands of the upper extremity	718	Lymph-glands of the upper extremity	718
Lymphatic vessels of the upper extremity	721	Lymphatic vessels of the upper extremity	721
Lymph-glands of the lower extremity	721	Lymph-glands of the lower extremity	721
Lymphatic vessels of the lower extremity	723	Lymphatic vessels of the lower extremity	723
Lymph-glands of the abdomen and pelvis	724	Lymph-glands of the abdomen and pelvis	724
1. Parietal lymph-glands	724	1. Parietal lymph-glands	724
2. Visceral lymph-glands	726	2. Visceral lymph-glands	726
Lymphatic vessels of the abdomen and pelvis	729	Lymphatic vessels of the abdomen and pelvis	729
1. Parietal lymphatic vessels	729	1. Parietal lymphatic vessels	729
2. Visceral lymphatic vessels	730	2. Visceral lymphatic vessels	730
(1) Lymphatic vessels of the subdiaphragmatic portion of the digestive tube	730	(1) Lymphatic vessels of the subdiaphragmatic portion of the digestive tube	730
(2) Lymphatic vessels of the spleen and suprarenal glands	732	(2) Lymphatic vessels of the spleen and suprarenal glands	732
(3) Lymphatic vessels of the urinary organs	732	(3) Lymphatic vessels of the urinary organs	732
(4) Lymphatic vessels of the reproductive organs	734	(4) Lymphatic vessels of the reproductive organs	734
Lymph-glands of the thorax	735	Lymph-glands of the thorax	735
1. Parietal lymph-glands	735	1. Parietal lymph-glands	735
2. Visceral lymph-glands	736	2. Visceral lymph-glands	736
Lymphatic vessels of the thorax	737	Lymphatic vessels of the thorax	737
1. Lymphatic vessels of the thoracic wall	737	1. Lymphatic vessels of the thoracic wall	737
2. Lymphatic vessels of the thoracic viscera	738	2. Lymphatic vessels of the thoracic viscera	738
NEUROLOGY		NEUROLOGY	
General description of nervous system	740	General description of nervous system	740
Structure of peripheral nerves and ganglia	741	Structure of peripheral nerves and ganglia	741
THE MEDULLA SPINALIS	745	THE MEDULLA SPINALIS	745
Structure	748	Structure	748

	PAGE		PAGE
THE ENCEPHALON OR BRAIN	760	THE CEREBAL NERVES (<i>continued</i>)	
The rhombencephalon or hind-brain	761	Mandibular nerve	860
Medulla oblongata	761	Otic ganglion	862
Pons	772	Submaxillary ganglion	863
Cerebellum	775	Abducent nerve	865
Fourth ventricle	783	Facial nerve	867
The mesencephalon or mid-brain	787	Acoustic nerve	872
Cerebral peduncles	787	Glossopharyngeal nerve	875
Corpora quadrigemina	791	Vagus nerve	877
The cerebral aqueduct	793	Accessory nerve	881
The prosencephalon or fore-brain	793	Hypoglossal nerve	882
Diencephalon	793	THE SPINAL NERVES	885
Thalamencephalon	793	Nerve-roots	885
Thalami	793	Spinal ganglia	885
Metathalamus	796	Size and direction of nerve-roots	885
Epithalamus	797	Connexions with sympathetic	887
Hypothalamus	798	Structure	887
Third ventricle	803	Divisions	887
Telencephalon	804	Posterior divisions of the spinal	
Cerebral hemispheres	804	nerves	887
Surfaces of cerebral hemispheres	805	Cervical nerves	887
Lobes of hemispheres	807	Thoracic nerves	889
Frontal lobe	808	Lumbar nerves	890
Parietal lobe	808	Sacral nerves	890
Occipital lobe	809	Coccygeal nerve	890
Temporal lobe	810	Anterior divisions of the spinal	
Insula	811	nerves	890
Limbic lobe	811	Cervical nerves	891
Rhinecephalon	812	Cervical plexus	891
Interior of the cerebral hemi-		Superficial branches	891
spheres	813	Deep branches (medial series)	894
Corpus callosum	814	Deep branches (lateral series)	895
Lateral ventricles	815	Brachial plexus	895
Corpus striatum	819	Supraclavicular branches	896
Caudate nucleus	819	Infraclavicular branches	897
Lentiform nucleus	819	Thoracic nerves	908
Claustrum	821	Lumbar nerves	911
Nucleus amygdalæ	821	Lumbar plexus	911
Internal capsule	821	Sacral and coccygeal nerves	917
External capsule	822	Sacral plexus	917
Fornix	823	Pudendal plexus	925
Interventricular foramen	825	THE SYMPATHETIC NERVOUS SYSTEM	928
Septum pellucidum	826	Cephalic portion of sympathetic	
Choroid plexus of lateral ven-		system	931
tricle	826	Cervical portion of sympathetic	
Tela chorioidea of third ventricle	827	system	932
Structure of the cerebral hemi-		Thoracic portion of sympathetic	
spheres	827	system	933
Structure of the cerebral cortex	829	Abdominal portion of sympathetic	
Special types of cerebral cortex	831	system	935
Motor tract	835	Pelvic portion of sympathetic	
Sensory tract	836	system	935
Meninges of the brain and medulla		Great plexuses of sympathetic	
spinalis	839	system	937
Dura mater	839	Cardiac plexus	937
Arachnoid	842	Celiac plexus	937
Subarachnoid cavity	842	Hypogastric plexus	940
Subarachnoid cisternæ	843	Pelvic plexuses	940
Arachnoidal granulations	844	THE ORGANS OF THE SENSES AND	
Pia mater	845	THE COMMON INTEGUMENT	
Ligamentum denticulatum	846	Organ of taste	942
THE CEREBRAL NERVES	846	Organ of smell	943
Olfactory nerves	847	Accessory sinuses of the nose	949
Optic nerve	848	Organ of sight	951
Oculomotor nerve	851	Tunics of the eye	951
Trochlear nerve	852	Fibrous tunic	951
Trigeminal nerve	853	Vascular tunic	955
Ophthalmic nerve	854	Retina	960
Ciliary ganglion	856		
Maxillary nerve	856		
Sphenopalatine ganglion	859		

CONTENTS

xiii

	PAGE		PAGE
Organ of sight (<i>continued</i>)		THE MALE GENITAL ORGANS	1164
Refracting media	964	The testes	1164
Aqueous humour	964	The ductus deferens	1168
Vitreous body	964	Vesiculae seminales and ejaculatory ducts	1169
Crystalline lens	965	The spermatic cord and its coverings	1170
Accessory organs of the eye	968	The scrotum	1171
Ocular muscles	968	The penis	1173
Eyebrows	973	The prostate	1176
Eyelids	973	Bulbo-urethral glands	1178
Conjunctiva	976		
Lacrimal apparatus	976	THE FEMALE GENITAL ORGANS	1178
Organ of hearing	979	The ovaries	1178
The external ear	979	The uterine tubes	1182
The middle ear, or tympanic cavity	984	The uterus	1183
Auditory ossicles	988	The vagina	1190
The internal ear, or labyrinth	993	The external organs	1191
The osseous labyrinth	993	The mammae	1192
The membranous labyrinth	996		
Peripheral terminations of nerves of general sensations	1005	THE DUCTLESS GLANDS	1195
The common integument	1008	The thyroid gland	1195
		The parathyroid glands	1198
SPLANCHNOLOGY		The thymus	1198
RESPIRATORY APPARATUS	1016	The spleen	1200
The larynx	1016	The suprarenal glands	1205
The trachea and bronchi	1027	The glomera carotica	1207
The pleurae	1031	The glomus coccygeum	1207
The mediastinal cavity	1035		
The lungs	1037	SURFACE ANATOMY AND SURFACE MARKINGS	
DIGESTIVE APPARATUS	1045	Surface anatomy of the head and neck	1209
The mouth cavity	1046	Surface markings of special regions of the head and neck	1213
The palate	1048	The cranium	1213
The salivary glands	1049	The face	1216
The teeth	1054	The nose	1217
The tongue	1064	The mouth	1217
The muscles of the tongue	1067	The eye	1220
The fauces	1072	The ear	1221
The palatine tonsils	1072	The neck	1223
The muscles of the palate and fauces	1074	Surface anatomy of the back	1224
The pharynx	1076	Surface markings of the back	1226
The muscles of the pharynx	1078	Surface anatomy of the thorax	1227
The oesophagus	1080	Surface markings of the thorax	1229
The abdomen	1082	Surface anatomy of the abdomen	1233
The peritoneum	1086	Surface markings of the abdomen	1235
The stomach	1098	Surface anatomy of the perinaeum	1241
The small intestine	1105	Surface markings of the perinaeum	1242
The large intestine	1114	Surface anatomy of the upper extremity	1244
The pancreas	1128	Surface markings of the upper extremity	1249
The liver	1133	Surface anatomy of the lower extremity	1254
Excretory apparatus of the liver	1140	Surface markings of the lower extremity	1259
UROGENITAL APPARATUS	1143		
The urinary organs	1143		
The kidneys	1143		
The ureters	1152		
The urinary bladder	1154		
The male urethra	1160		
The female urethra	1163		

CORRIGENDA.

- Page 46, line 1, for 'of' read 'or.'
 „ 305, last line, for 'bladder' read 'urinary bladder.'
 „ 356, fig. 465, for 'Anterior longitudinal ligament' read 'Posterior longitudinal ligament.'
 „ 480, last line, for 'peistropheus' read 'epistropheus.'
 „ 548, par. 7, line 3, for 'tube' read 'tubes.'
 „ 874, line 3, for 'lateral' read 'labial.'
 „ 972, line 22, for 'sheath' read 'sheaths.'
 „ 1084, par. 8, line 2, for 'line' read 'lineæ.'



HUMAN ANATOMY

INTRODUCTION

THE term *human anatomy* comprises a consideration of the various structures which make up the human organism. In a restricted sense it deals merely with the parts which form the fully developed individual and which can be rendered evident to the naked eye by various methods of dissection. Regarded from such a standpoint it may be studied by two methods: (1) the various structures may be separately considered—*systematic anatomy*; or (2) the organs and tissues may be studied in relation to one another—*topographical or regional anatomy*.

It is, however, of much advantage to add to the facts ascertained by naked-eye dissection those obtained by the use of the microscope. This introduces two fields of investigation, viz. the study of the minute structure of the various component parts of the body—*histology*; and the study of the human organism in its immature condition, i.e. the various stages of its intra-uterine development from the fertilised ovum up to the period when it assumes an independent existence—*embryology*. Owing to the difficulty of obtaining material illustrating all the stages of this early development, gaps must be filled up by observations on the development of lower forms—*comparative embryology*, or by a consideration of adult forms in the line of human ancestry—*comparative anatomy*. The direct application of the facts of human anatomy to the various pathological conditions which may occur constitutes the subject of *applied anatomy*. Finally, the identification of structures on or immediately underlying the surface of the body is frequently made the subject of special study—*surface anatomy*.

SYSTEMATIC ANATOMY.—The various systems of which the human body is composed are grouped under the following headings:

1. *Osteology*—the bony system or skeleton.
2. *Syndesmology*—the articulations or joints.
3. *Myology*—the muscles. With the description of the muscles it is convenient to include that of the fasciæ which are so intimately connected with them.
4. *Angiology*—the vascular system, comprising the heart, blood-vessels, lymphatic vessels and lymph glands.
5. *Neurology*—the nervous system. The organs of the senses may be included in this system.
6. *Splanchnology*—the visceral system. Topographically the viscera form two groups, viz. the thoracic viscera and the abdominopelvic viscera. The heart, a thoracic viscus, is best considered with the vascular system. The rest of the viscera may be grouped according to their functions: (a) the *respiratory apparatus*; (b) the *digestive apparatus*; and (c) the *urogenital*

apparatus. Strictly speaking, the third sub-group should include only such components of the urogenital apparatus as are included within the abdomino-pelvic cavity, but it is convenient to study under this heading certain parts which lie in relation to the surface of the body, e.g. the testes and the external organs of generation.

For descriptive purposes the body is supposed to be in the erect posture, with the arms hanging by the sides and the palms of the hands directed forwards. The *median plane* is a vertical anteroposterior plane, passing through the centre of the trunk. This plane will pass approximately through the sagittal suture of the skull, and hence any plane parallel to it is termed a *sagittal plane*. A vertical plane at right angles to the median plane passes, roughly speaking, through the central part of the coronal suture or through a line parallel to it; such a plane is therefore known as a *coronal plane*. A plane at right angles to both the median and frontal planes is termed a *transverse* or *horizontal plane*.

The terms *anterior* or *ventral*, and *posterior* or *dorsal*, are employed to indicate the relation of parts to the front or back of the body or limbs, and the terms *superior* or *cephalic*, and *inferior* or *caudal*, to indicate the relative levels of different structures; structures nearer to or farther from the median plane are referred to as *medial* or *lateral* respectively.

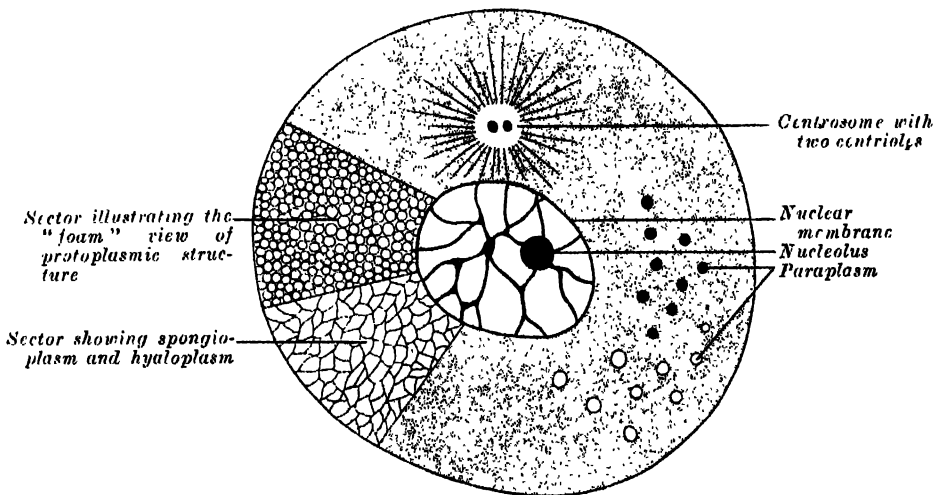
The terms *superficial* and *deep* are strictly confined to descriptions of the relative depth from the surface of the various structures: *external* and *internal* are reserved almost entirely for describing the walls of cavities or of hollow viscera. In the case of the limbs the words *proximal* and *distal* refer to the relative distance from the attached end of the limb.

HISTOLOGY

THE ANIMAL CELL

ALL the tissues and organs of the body originate from the fertilised ovum, a microscopic structure consisting of a jelly-like material enclosed in a membrane, and containing a small, spherical, more solid body in its interior; the contained body is called a nucleus, and within it are found one or two distinct spots, termed nucleoli. The fertilised ovum divides and subdivides into an enormous number of similar structures, which are known as cells, and these become variously modified according to the function which they have to perform. Although the cells of the different tissues and organs vary considerably in shape, size, and other characteristics, each consists of a semi-fluid material, known as *protoplasm*, and contains a nucleus. A cell may therefore be defined as a minute nucleated mass of protoplasm (fig. 1).

FIG. 1.—Diagram of a cell.



Protoplasm varies in composition, but in all cases it yields, on analysis, nitrogenous substances, known as proteins. When examined with high powers of the microscope it may appear homogeneous, but many cells show some degree of differentiation into fibrils or granules. After fixation with reagents, such as mercuric chloride, most cells exhibit a reticular, or rather a sponge-like structure, which has a greater affinity for dyes than the material contained in its meshes. It was formerly believed that living protoplasm had a similar structure, and consisted of a fibrillar network, or *spongioplasm*, with a more fluid material, or *hyaloplasm*, in its interstices. The view most commonly held at the present time, however, is that the large molecules of which protoplasm is composed are so arranged as to form two distinct 'phases.' The result is a structure resembling foam, and consisting of minute spaces containing fluid material and bounded by a less fluid phase

formed by a closer aggregation of the molecules. Whether this view be correct or not, it is convenient in the meantime to retain the terms spongioplasm and hyaloplasm to indicate the structure seen in the fixed and stained cell.

The protoplasm of cells frequently contains granules of foreign material, such as glycogen, fat, or pigment. These may have been either formed in the cell or taken in from without, and are spoken of as *paraplast* or *deuterooplasm*.

Few animal cells resemble the ovum in possessing a definite cell-membrane: in those which do not, the surface exhibits certain physical properties which point to a local condensation of some of the protoplasmic constituents. According to Overton these are of a fatty nature and are known as lipoids.

The **nucleus**, in fixed and stained preparations, exhibits a differentiation into a network, or *karyomitome*, and a more fluid material, or *karyoplasm*, in the meshes of the network. The karyomitome is condensed at the periphery of the nucleus to form a well-defined wall, the *nuclear membrane*, and consists of particles of a substance, called *chromatin* because of its affinity for basic dyes, imbedded in a homogeneous material, *linin*, which stains with acid dyes. The staining properties of chromatin are due to the presence of nucleic acid.

The **nucleolus** is a small, spherical, highly refracting body, which stains with acid dyes. Nodes of the chromatin network are liable to be mistaken for nucleoli, but may be distinguished by their irregular shape and staining affinities; they are known as *pseudonucleoli*.

A **centrosome** is present in most cells. It lies near the nucleus, and consists of a small, spherical area of clear protoplasm, in the middle of which is a minute spot or *centriole*. The centrosome is often called the *attraction sphere* because rows of granules in the protoplasm immediately surrounding it are arranged so that they radiate outwards from it like the rays of the conventional sun.

Reproduction of cells is effected either by *direct* or by *indirect division*. In reproduction by *direct division* the nucleus becomes constricted in its centre, assuming an hour-glass shape, and then divides into two. This is followed by a cleavage or division of the whole protoplasmic mass of the cell; and thus two daughter cells are formed, each containing a nucleus. The daughter cells are at first smaller than the original mother cell; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. Direct division is said to occur in the epithelial cells lining the bladder. *Indirect division* or *karyokinesis* (*karyomitosis*) has been observed in generative cells, epithelial cells, connective tissue-cells, muscular tissue, and nerve-cells. It is possible that cell-division may always take place by the indirect method, and that in those cases in which direct division has been described the intermediate stages may not have been seen; owing to the process occurring more rapidly than usual.

The process of indirect cell-division is characterised by a series of complex changes in the nucleus, leading to its subdivision; this is followed by cleavage of the cell protoplasm. Starting with the nucleus in the quiescent or *resting* stage, these changes may be briefly grouped under the three following phases (fig. 2):

1. **Anaphase**.—The nuclear network of chromatin filaments assumes the form of a twisted *skein* or *spirem*, while the nuclear membrane and nucleolus disappear. The convoluted skein of chromatin divides into a definite number of V-shaped segments or *chromosomes*. The number of chromosomes varies in different animals, but is constant for all the cells in an animal of any given species; in man the number is given by Flemming and Duesberg as twenty-four.* Coincidentally with or preceding these changes, the centrosome, which usually lies by the side of the nucleus, undergoes subdivision, and the two resulting centrosomes are seen to be connected by a spindle of delicate achromatic fibres, the *achromatic spindle*. The centrosomes move away from each other—one towards either extremity of the nucleus—and the fibrils of the achromatic spindle are correspondingly lengthened. A line encircling the spindle midway between its extremities or *poles* is named the *equator*, and around this the V-shaped chromosomes arrange themselves in the form of a star, thus constituting the *monaster*.

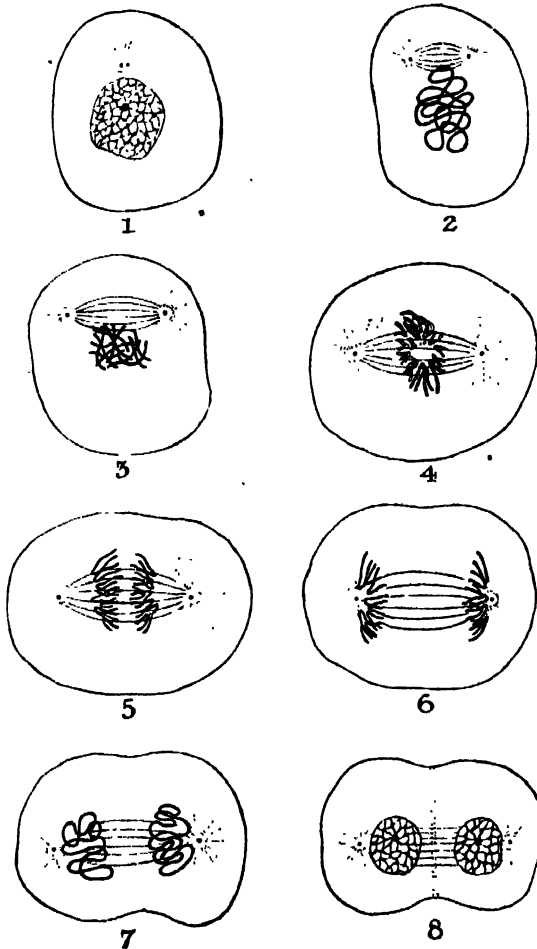
2. **Metaphase**.—Each V-shaped chromosome undergoes longitudinal cleavage into two equal parts or *daughter chromosomes*, the cleavage commencing at the apex of the V and extending along its divergent limbs. The daughter chromosomes, thus separated, travel in opposite directions along the fibrils of the achromatic spindle towards the centrosomes, around which they group themselves, and thus

* Dr. J. Duesberg, *Anat. Anz.*, Band xxviii, S. 475.

two star-like figures are formed, one at either pole of the achromatic spindle. This constitutes the *diaster*.

3. *Kataphase*.—The daughter chromosomes arrange themselves into a *skein* or *spirem*, and eventually form the network of chromatin which is characteristic of the resting nucleus. The nuclear membrane and nucleolus are also differentiated during this phase. The cell-protoplasm begins to appear constricted around the equator of the achromatic spindle, where double rows of granules are also sometimes seen. The constriction deepens and the original cell is gradually divided.

FIG. 2.—Diagram showing the changes which occur in the centrosome and nucleus of a cell in the process of mitotic division, as seen in the epidermis of a larval salamander.



1 to 4 Anaphase ; 5 and 6, Metaphase ; 7 and 8, Kataphase.

The term *telophase* is sometimes applied to the concluding steps of the process of division, in which the daughter cells are finally separated and their nuclei and centrosomes assume the characteristics of the resting stage.

Heterotypical and homotypical mitosis.—In the case of the cells of the reproductive glands the mitotic process differs from that described above. After the formation of the chromosomes, pairs of these structures become connected by their ends so as to form elongated rings. The centrosomes of the daughter nuclei are formed by the breaking of these rings across the middle. Each chromosome then splits in its length into two. No kataphase occurs, and division of the original cell takes place. This process is known as *heterotypical mitosis*, and it is immediately

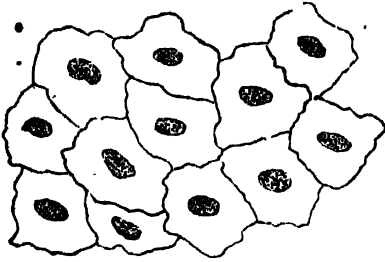
HISTOLOGY

followed by a division of each daughter cell, known as *homotypical mitosis*, in which the chromosomes separate into two equal groups, one group for each new cell. Each nucleus resulting from homotypical mitosis has thus one-half of the number of chromosomes normal for the species, and it passes through a kataphase to form a typical resting nucleus.

EPITHELIUM

All the surfaces of the body—the external surface of the skin, the internal surfaces of the digestive, respiratory, and genito-urinary tracts, the closed serous cavities, the inner coats of the vessels, the acini and ducts of all secreting and ex-

FIG. 3.—Simple pavement epithelium.



creting glands, the ventricles of the brain and the central canal of the medulla spinalis—are covered by one or more layers of cells, called *epithelium* or *epithelial cells*. These cells are also present in the terminal parts of the organs of special sense, and in some other structures, such as the hypophysis cerebri and the thyroid gland. They serve various purposes. Thus, in the skin, the main purpose served by the epithelium (here called the *epidermis*) is that of protection; as the surface is worn away by the agency of friction new cells

are supplied, and thus the true skin and the vessels and nerves which it contains are defended from damage. The epithelial cells of the salivary glands, the pancreas, the gastric glands, and the glands of the small intestine prepare the digestive juices; those covering the intestinal villi are concerned with the absorption of the products of digestion; similar cells lining the kidney tubules excrete waste products; others, such as those lining the serous cavities, provide a smooth, moist surface.

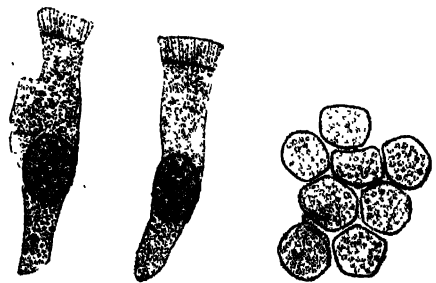
Epithelium consists of one or more layers of cells, usually supported on a basement membrane, and united together by cement substance, which is similar in chemical composition to the matrix or ground substance of the connective tissues, and has the property of reducing nitrate of silver. Epithelium is naturally grouped into two classes according to whether there is a single layer of cells (*simple epithelium*), or more than one (*stratified epithelium* and *transitional epithelium*).

Simple epithelium.—The different varieties of simple epithelium are squamous or pavement, columnar, glandular, and ciliated.

Simple squamous or *pavement epithelium* (fig. 3) is composed of flat, nucleated cells of different shapes, usually polygonal, and varying in size. These cells fit together by their edges, like the tiles of a mosaic pavement. The nucleus is generally flattened, but may be spheroidal. The protoplasm of the cell may be fibrillated, the fibrils of adjacent cells being continuous across the intervening cement. This kind of epithelium forms the lining of the alveoli of the lungs. The so-called *endothelium*, which covers the serous membranes, and which lines the heart, blood-vessels and lymphatics, is also of the pavement type.

Columnar or *cylindrical epithelium* (fig. 4) consists of cylindrical or rod-shaped cells set together so as to form a complete layer, resembling, when viewed in profile, a palisade. The cells have a prismatic figure, from mutual pressure, and are set upright on the surface which supports them. The cell-protoplasm is always more or less reticulated; the nucleus is oval in shape and contains an intranuclear network;

FIG. 4.—Columnar epithelial cells from the small intestine of the cat. $\times 600$.



a, side view; b, cells seen from surface.

the centriole is double and lies near the surface of the cell. In the columnar epithelium of the intestinal villi, the free border of each cell shows a refractive cap which exhibits well-defined vertical striations. Columnar epithelium lines nearly the whole gastro-intestinal tract and its glands, the greater part of the male urethra, the ductus deferens, the tubules and ducts of the prostate, the bulbo-urethral glands of Cowper, and the vestibular glands of Bartholin. In a modified form it also covers the ovary.

Goblet- or chalice-cells are modified columnar cells. Each appears to be formed by an alteration in shape of a columnar cell (ciliated or otherwise) consequent on the formation of granules, which consist of a substance called *mucigen*, in the interior of the cell. This distends the upper part of the cell, while the nucleus is pressed down towards its deep part, until the cell bursts and the mucus is discharged on to the surface of the mucous membrane (fig. 5), the cell then assuming the shape of an open cup or chalice. A double centriole is found in the mucin-containing part of the goblet cell. Cells of this kind are especially numerous in the mucous membrane of the stomach, and in the glands of the large intestine; they also occur in the epithelial covering of the villi of the small intestine and in that lining the respiratory tract (fig. 7).

Glandular epithelium (fig. 6) is composed of polyhedral, columnar or cubical

FIG. 5.—Goblet cells of a frog
× 500.

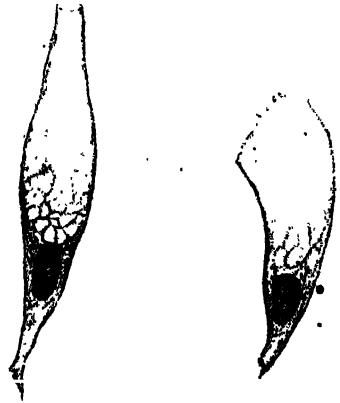
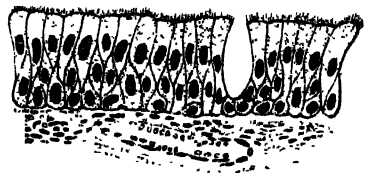


FIG. 6.—Isolated liver cells of a rabbit. × 500.



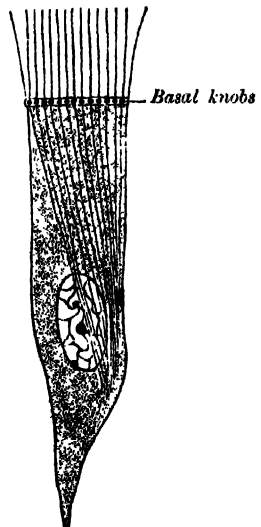
FIG. 7.—Ciliated epithelium from the trachea of a kitten. × 255.



cells. The protoplasm shows a fine reticulum, which gives to the cells a granular appearance. Besides these protoplasmic 'granules,' gland cells usually contain true granules which are the products of their own activity. These are in many cases zymogenic in nature, that is, they are, or contain, the precursors of enzymes or ferments.

Ciliated epithelium (fig. 7) is generally columnar in shape. It is distinguished by the presence of minute processes, like hairs or eyelashes (cilia), standing up from the free surface. The cilia (fig. 8), at their points of attachment to the free border of the cell, possess small nodular enlargements (*basal knobs* of Engelmann); from these knobs fine beaded filaments extend through the cell, and converge to a point near the fixed extremity. The basal knobs or particles have been supposed to be formed by division of the centriole. If the cells be examined during life or immediately on removal from the living body (for which in the human subject the removal of a nasal polypus offers a convenient opportunity) in a weak solution of salt, the cilia will be seen in lashing motion; and if the cells be separated, they will often be seen to be moved about in the field by this ciliary action.

FIG. 8.—Isolated ciliated cell (semidiagrammatic).



Ciliated epithelium lines the respiratory tract from the nose downwards to the smallest ramifications of the bronchial tubes (except in the lower part of the pharynx and on the surfaces of the vocal folds); the tympanic cavity and auditory tube; the uterine tube and the cavity of the body of the uterus; the vasa efferentia; coni vasculosi and the first part of the ductus deferens; the ventricles of the brain and the central canal of the medulla spinalis.

FIG. 9.—Stratified epithelium from the œsophagus.

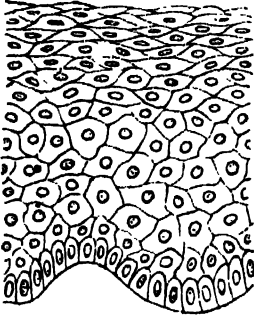
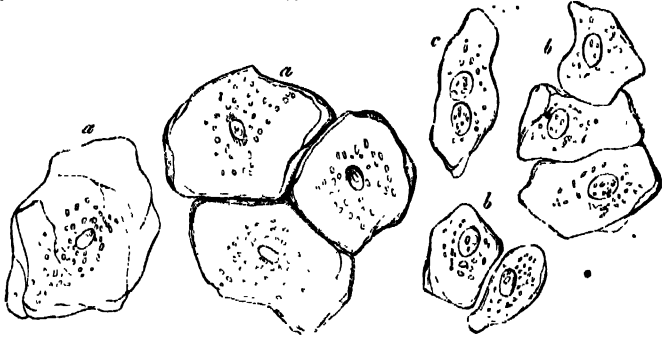


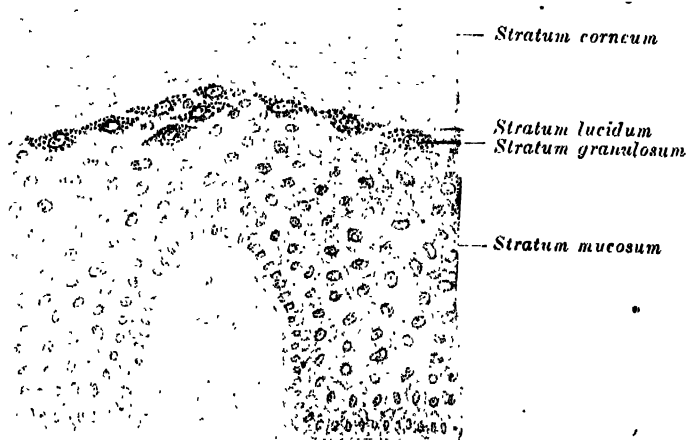
FIG. 10.—Epithelial cells from the oral cavity of man. $\times 350$.



a. Superficial. b. From deeper layers. c. Cell with two nuclei.

Stratified epithelium (fig. 9) consists of several layers of cells. The cells vary greatly in shape; those of the deepest layer are for the most part columnar, and are placed vertically on the basement membrane; above these are several layers of polyhedral cells, which as they approach the surface become more and more compressed, until the superficial ones are found to consist of flattened scales (fig. 10),

FIG. 11.—Portion of epidermis from a section of the skin of the sole of the foot. $\times 250$.



which overlap one another so as to present an imbricated appearance. The epithelium of the skin, or epidermis, is peculiar in that it shows four distinct layers. The deep layer consists of columnar and polyhedral cells as in stratified squamous epithelium generally (stratum mucosum). In the next layer, or stratum granulosum, the cells are fusiform in section, and contain granules of a substance called *eleidin*. The third layer, or stratum lucidum, consists of cells in which the eleidin has undergone a transformation into a substance called *keratohyalin*; and the cells of the

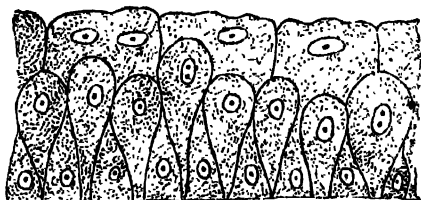
most superficial layer (stratum corneum) are completely converted into a horny material, known as *keratin* (fig. 11).

The cells of the deeper layers of stratified squamous epithelium are called *prickle-cells*; they are not closely joined together by cement-substance, but are separated from each other by intercellular channels, between which are protoplasmic bridges containing fine fibrils which connect the adjacent cells with each other. When a cell is isolated, it appears to be covered over with a number of short spines, in consequence of the bridges being broken through.

Stratified epithelium is found in the skin, in the conjunctiva, on the anterior surface of the cornea, and in the mucous membrane of the mouth, lower part of the pharynx, œsophagus, vagina and part of the cervix uteri.

Transitional epithelium occurs in the ureters and urinary bladder. Here the cells of the most superficial layer are large and flattened, with depressions on their under surfaces to fit on to the rounded ends of the cells of the second layer, which are pear-shaped, the apices touching the basement membrane. Between the tapering points of the cells of the second layer is a third variety of cells of smaller size than those of the other two layers (fig. 12). In the distended condition of the bladder the superficial cells are more flattened, and the pear-shaped cells are shorter and broader than they are when the bladder is contracted.

FIG. 12.—Transitional epithelium.



CONNECTIVE TISSUES

The term **connective tissue** includes a number of tissues which have a passive function, that of binding together or supporting the functionally active structures; they differ considerably from each other in appearance, but present many points of relationship, and are, moreover, developed from the same layer of the embryo, the mesoderm. They are divided into three great groups: (1) the connective tissues proper, (2) cartilage, and (3) bone.

The circulating fluids (although functionally and probably developmentally different) are regarded by some histologists as a form of connective tissue, and are dealt with in this section.

THE CONNECTIVE TISSUES PROPER

Several varieties of connective tissue are recognised: (1) Areolar tissue. (2) White fibrous tissue. (3) Yellow elastic tissue. (4) Mucous tissue. (5) Retiform tissue. They are all composed of a homogeneous matrix, in which are imbedded cells and fibres—the latter of two kinds, white, and yellow or elastic. The distinction between the different varieties depends upon the relative preponderance of one or other kind of fibre, of cells, or of matrix.

Areolar tissue (fig. 13) is so called because, when artificially distended with air or fluid, it exhibits intercommunicating areolæ or spaces. It is extensively distributed and its chief use is to bind parts together, though allowing, in virtue of its extensibility and elasticity, a considerable amount of movement to take place. It occurs as subcutaneous tissue, as the submucous coat in the digestive tract and elsewhere, and as subserous tissue. It is also found between muscles, vessels, and nerves, forming investing sheaths for them, and connecting them with surrounding structures. It is present in the interior of organs, binding together the lobes and lobules of the compound glands, the various coats of the hollow viscera, and the fibres of muscles and nerves.

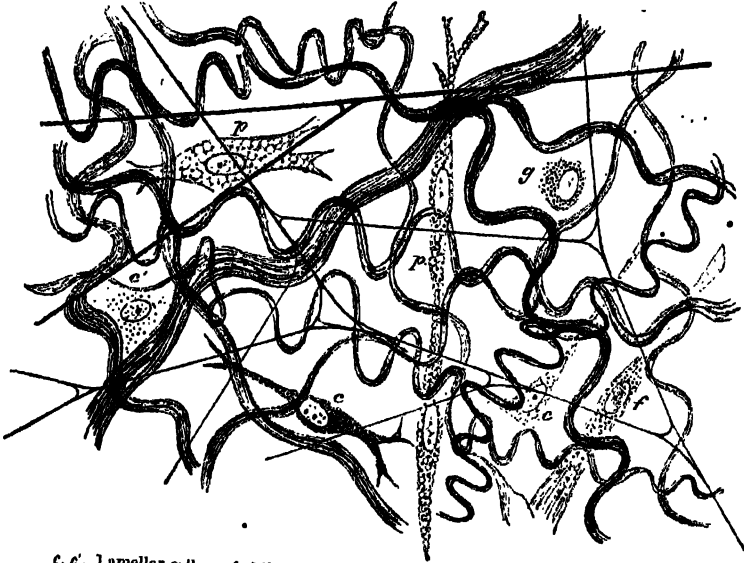
When areolar tissue is stretched it is seen to be made up of soft elastic threads, resembling spun silk, and interlacing in all directions. A thin layer, examined under the microscope, shows fibres and cells, imbedded in a homogeneous ground substance or *matrix*.

The fibres form an irregular meshwork, and are of two kinds, white and yellow. The *white fibres* are exceedingly fine; they are colourless, homogeneous and

HISTOLOGY

transparent, and are arranged parallel to each other in bundles, which have a wavy course. The individual fibres do not branch, but small bundles of them may leave one

FIG. 13—Subcutaneous tissue from a young rabbit. Highly magnified. (From .. Schäfer's Essentials of Histology.)



c, c'. Lamellar cell. f. Fibrillated cell. g. Plasma-cell. p. Clasmatocytes.

large bundle to join another. The *yellow* or *elastic* fibres have well-defined outlines, and are usually somewhat larger than the white fibres, varying in diameter from

FIG. 14—Areolar tissue of a rabbit, silvered. $\times 255$.
Ground substance stained, cells unstained.



1μ to 6μ .* They are pale yellow in colour, homogeneous in appearance, run a comparatively straight course, branch, and anastomose freely with each other.

* A micromillimetre (μ) is $\frac{1}{1000}$ of a millimetre or $\frac{1}{25400}$ of an inch.

When they are broken across, the ends tend to curl up. They also differ from the white fibres in staining a dark red colour with orcein.

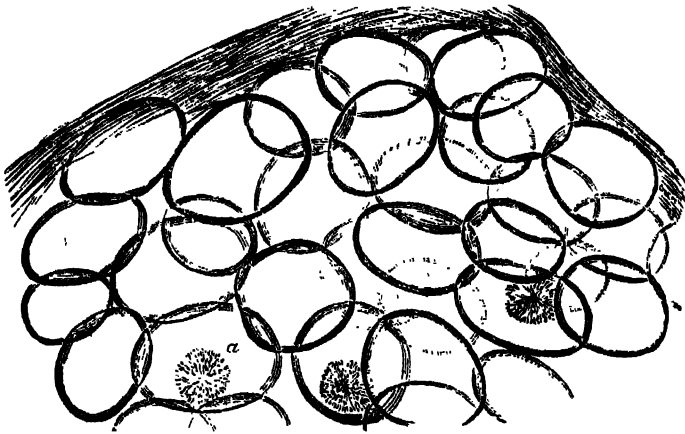
The cells of areolar tissue are of four principal kinds: (1) Flattened *lamellar cells*, may be either branched or unbranched. The branched lamellar cells are composed of clear protoplasm, with few granules, and contain oval nuclei; their processes may unite with those of neighbouring cells, so as to form a syncytium, as in the cornea. Occasionally a cell may be found which shows fibrillation of its protoplasm. Some observers believe such a condition to be a stage in the formation of the white fibres. The unbranched cells are joined edge to edge like the cells of an epithelium; the flattened cells lining the serous cavities are examples of this variety. (2) *Clasmatocytes* are large irregular cells characterised by the presence of granules or vacuoles in their protoplasm, and containing oval nuclei. (3) *Granule-cells* are ovoid or spheroidal in shape and contain basiphil granules. (4) *Plasma-cells* of Waldeyer are usually spheroidal in shape and distinguished by containing a vacuolated protoplasm; the vacuoles are filled with fluid, and the protoplasm between them is clear, with occasionally a few scattered basiphil granules.

In addition to these four types of cells, areolar tissue may contain *wandering cells*, i.e. leucocytes which have emigrated from the neighbouring vessels; in some instances, as in the choroid coat of the eye, cells filled with granules of pigment (*pigment-cells*) are found.

The cells lie in spaces in the ground substance between the bundles of fibres, and these spaces may be brought into view by treating the tissue with nitrate of silver and exposing it to the light; this will colour the ground substance and leave the cell-spaces unstained (fig. 14).

Adipose tissue.—In almost all parts of the body areolar tissue contains a variable quantity of adipose tissue or fat. The principal situations where it is not found are the subcutaneous tissue of the eyelids, of the penis and scrotum, of the labia minora; within the cavity of the cranium; and in the lungs, except near their

FIG. 15.—Adipose tissue. Highly magnified.



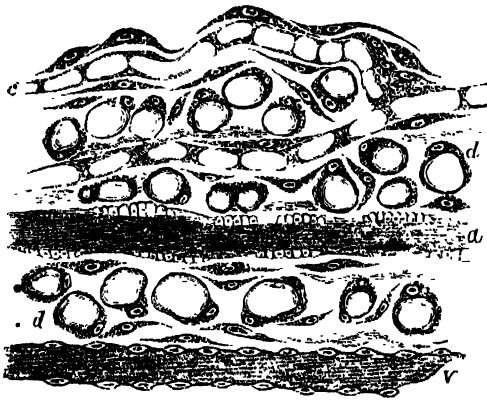
α . Starlike appearance, from crystallisation of fatty acids.

roots. The distribution of adipose tissue is not uniform; in some parts it is in great abundance, as in the subcutaneous tissue, especially of the abdomen, around the kidneys, and in the mesentery and omentum. Lastly, fat enters largely into the formation of the marrow of bones.

Adipose tissue consists of *fat-cells*, lodged in the meshes of areolar tissue. Fat-cells (fig. 15) vary in size, the average diameter being about 50μ ; each consists of an exceedingly delicate protoplasmic membrane, filled with fatty matter, which is liquid during life, but solidifies after death. They are round or spherical where they are not subjected to pressure; otherwise they are more or less polygonal. A nucleus is always present under the cell-membrane and can be demonstrated by staining with hæmatoxylin; in the natural condition it is so compressed by the

contained oily matter as to be scarcely recognisable. The fat-cells are held together mainly by the network of capillary blood-vessels which is distributed to them.

FIG. 16.—Development of fat.
(Klein and Noble Smith.)



a. Minute artery. r. Minute vein. c. Capillary blood-vessels in the course of formation; they are not yet completely hollowed out, there being still left in them protoplasmic septa. d. The ground-substance, containing numerous nucleated cells, some of which are more distinctly branched and flattened than others, and appear therefore more spindle-shaped.

Chemically the oily material is composed of olein, palmitin, and stearin, which are glycerol esters of fatty acids. Sometimes fat-crystals form in the cells after death (fig. 15. a). By boiling the tissue in ether or strong alcohol, the fat may be extracted from the cells, leaving them empty and shrunken.

Fat first appears in the human embryo about the fourteenth week. The fat-cells are formed by the transformation of connective tissue cells. Small droplets of oil are formed in the protoplasm, and these coalesce to produce a larger drop, which increases until it distends the cell, the remaining protoplasm and the nucleus being displaced towards the periphery (fig. 16).

White fibrous tissue is a true connecting structure, and serves three purposes in the animal economy. In the form of ligaments it binds bones together; in the form of tendons it connects muscles with bones or other structures; it constitutes investing or protecting membranes to various organs. Examples of such membranes are to be found in the muscular fasciæ or sheaths, the periosteum, and the perichondrium; the capsules of the various glands; the investing sheaths of the nerves (perineurium), and of various organs, as the penis and the eye.

In white fibrous tissue, as its name implies, the white fibres (fig. 17) predominate: the matrix is apparent only as a cement-substance, yellow elastic fibres

FIG. 17.—White fibres. $\times 350$.

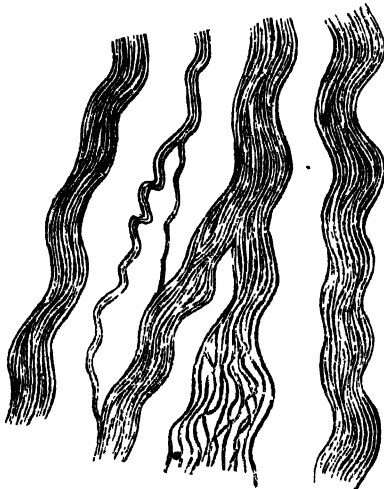
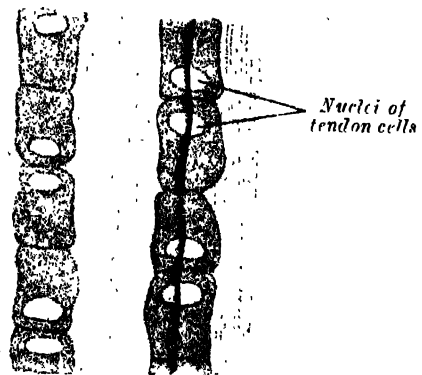


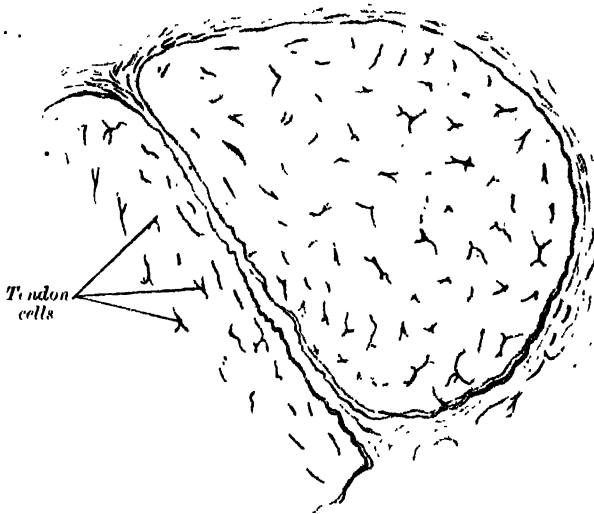
FIG. 18.—Tendon of a rat's tail, stained with gold chloride, showing chains of cells between the tendon-bundles. $\times 250$.



are comparatively few, while the tissue-cells are arranged in a special manner. It presents to the naked eye a silvery white glistening appearance; it is devoid of elasticity, and has only the very slightest extensibility; it is exceedingly strong, so that upon the application of any external violence, a bone with which it is connected may fracture before the fibrous tissue gives way. In ligaments and tendons the bundles of fibres run parallel with each other; in membranes they intersect

one another. The cells found in white fibrous tissue are often called 'tendon-cells.' They are situated on the surfaces of groups of fibres, and are arranged in rows, each cell being separated from its neighbours by a narrow line of cement-substance. The nucleus is generally situated at one end of the cell, the nucleus of the adjoining cell being in close proximity to it (fig. 18). The tendon-cells have

FIG. 19.—Transverse section of a tendon of a rat. $\times 120$.



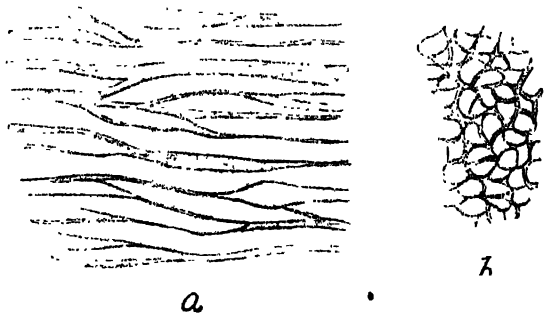
wing-like processes which pass between the bundles of fibres, giving a stellate appearance in transverse section (fig. 19). When viewed from the side, the cell with its wings is quadrangular, and there may be the appearance of a vertical line on the body of the cell owing to the projection of a wing towards the eye of the observer (fig. 18). Upon the addition of acetic acid white fibrous tissue swells up into a glassy-looking indistinguishable mass. When boiled in water it is converted almost completely into gelatin, the white fibres being composed of *collagen*, which is regarded as the anhydride of gelatin.

Yellow elastic tissue.—In certain parts of the body a tissue is found which is of a yellowish colour, and possessed of great elasticity. It is capable of considerable

extension, and when the extending force is withdrawn returns at once to its original condition. This is *yellow elastic tissue*; it may be regarded as a connective tissue in which the yellow elastic fibres have developed to the practical exclusion of the other elements. It is found in the ligamenta flava, in the vocal folds and conus elasticus of the larynx, in the mucous membrane of the trachea and bronchi, in the walls of the pulmonary air-vesicles, in the coats of the blood-vessels, especially the

larger arteries, and to a very considerable extent in the hyothyroid and stylohyoid ligaments. It is also found in the ligamentum nuchæ of the lower animals (fig. 20). Where the fibres are broad and large and the network close, the tissue presents the appearance of a membrane, with gaps or perforations corresponding with the intervening spaces. This is found in the inner coat of the arteries, and to it the name of *fenestrated membrane* has been given by Henle. Yellow elastic fibres

FIG. 20.—Ligamentum nuchæ of the ox, stained with picrocarmine. $\times 280$.



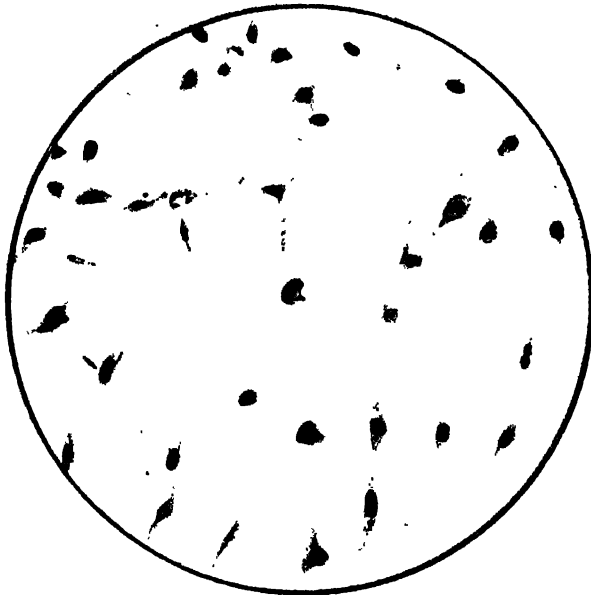
a. Longitudinal section. b. Transverse section.

remain unaltered by acetic acid; chemically they are composed of the sclero-protein known as *elastin*.

Mucous tissue exists in the 'jelly of Wharton,' which forms the bulk of the umbilical cord, but is also found in the foetus, chiefly as a stage in the development of connective tissue. It consists of a matrix, largely made up of mucin, in which are nucleated cells with branching and anastomosing processes (fig. 21). Few fibres are seen in typical mucous tissue, though at birth the umbilical cord shows a considerable development of fibres. In the adult the vitreous body of the eye is a persistent form of mucous tissue, in which the fibres and cells are very few in number.

Retiform or reticular tissue (fig. 22) is found extensively in many parts of the body, constituting the framework of some organs and entering into the construction of many mucous membranes. It is a variety of connective tissue, in which the intercellular or ground-substance is, in a great measure, replaced by fluid. It is composed almost entirely of extremely fine bundles of white fibrous tissue,

FIG. 21.—Mucous tissue from the umbilical cord of a human embryo of four months.
× 255. Stained with hæmatoxylin and eosin.



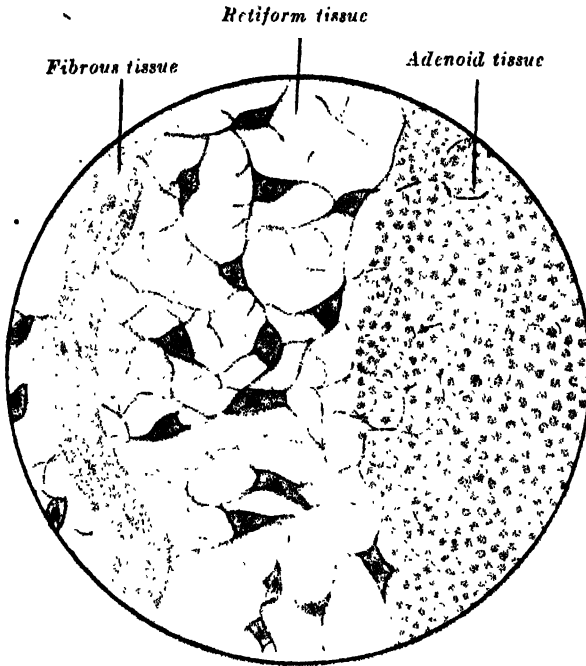
forming an intricate network, and chemically it yields *gelatin* on boiling. The fibres are covered and concealed in places by flattened branched connective tissue cells. In many situations the interstices of the network are filled with rounded lymph-corpuscles, and the tissue is then termed **lymphoid** or **adenoid tissue**.

Basement membranes consist of thin sheets of modified connective tissue, and are found underlying layers of epithelial cells, for example, in mucous membranes and secreting glands. They may be formed of cells or of condensed ground-substance. In the former case, flattened cells, which are modified connective tissue corpuscles, are united by their edges by means of cement-substance, which can be demonstrated by staining with silver nitrate; if the cells are unbranched, the membrane is continuous; if they are branched, the processes are united, and the membrane is fenestrated. The basement membrane underlying the epithelium on the anterior surface of the cornea is composed of ground-substance.

Vessels and nerves of connective tissue.—The *blood-vessels* of connective tissue are very few—that is to say, few are supplied to the tissue itself, although many carrying blood to other structures may permeate one of its forms, the areolar tissue. In white fibrous tissue the blood-vessels usually run parallel to and between the longitudinal bundles, sending communicating branches across the bundles; in some forms, as in the periosteum and dura mater, they are fairly numerous. In yellow elastic tissue, the blood-vessels also run between the fibres. *Lymphatic*

vessels are very numerous in most forms of connective tissue, especially in the areolar tissue beneath the skin and the mucous and serous surfaces. They are also found in abundance in the sheaths of tendons, as well as in the tendons themselves.

FIG. 22.—Retiform and adenoid tissue, from a lymph gland. $\times 255$.



Nerves are found in white fibrous tissue, where they end in a special manner; but it is doubtful whether any nerves end in areolar tissue; at all events, they have not yet been demonstrated, and the tissue is possessed of very little sensibility.

Pigment.—Pigment is found in various parts of the body; most frequently in epithelial cells and in the cells of connective tissue. Pigmented *epithelial cells* are present in the external layer of the retina, on the posterior surface of the iris, in the olfactory region of the nose, in the membranous labyrinth of the ear, in the deeper layers of the cuticle, and in the hairs. Pigment is abundantly present in the skin of the coloured races, but in the skin of white races it is well marked only in the areolæ round the mammary papillæ and in irregular coloured patches. Pigmented *connective tissue cells* are frequently met with in the lower vertebrates. In man they are found in the chorioid coat of the eye (fig. 23), and in the iris of all but the light blue eyes and the albino. The cells are usually large and branched, and are filled with brown or black granules, consisting of *melanin*. In the retina the processes of the cells extend between the rods and cones; when the eye is exposed to light the pigment-granules extend into these processes, and under the influence of darkness they are withdrawn into the body of the cell.

FIG. 23.—Pigment-cells from the chorioid coat of the eyeball.



The pigment-granules are of very small size and are closely packed within the cells, but do not invade the nuclei. Occasionally they are yellow, and when occurring in the cells of the cuticle constitute 'freckles.' In the retina another variety of pigment occurs, known as *rhodopsin* or *visual purple*, which is bleached on exposure to light.

Applied Anatomy.—Abnormal pigmentation of the skin may be congenital, when it often takes the form of dark brown or black *nævi* (moles), scattered over a greater or smaller area of the body. It may also result from the prolonged consumption of various drugs, particularly of salts of silver or arsenic, being most marked wherever the skin is exposed to the action of light. Progressive darkening or bronzing of the skin is also highly suggestive of Addison's disease, which commonly follows destruction or tuberculosis of the suprarenal glands; it is then most obvious in regions where the skin is normally pigmented or is subjected to pressure or irritation from the clothes. Pigmentation is also associated with certain disorders of the skin, of the female genitalia, and of the thyroid gland, and with the later stages of wasting diseases such as cancer and phthisis. It does not yield to any medical treatment as a rule.

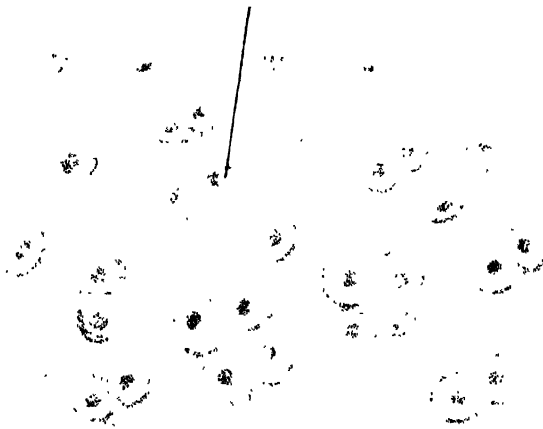
• **Development of connective tissue.**—Connective tissue is developed from cells of the mesoderm. These cells multiply and form a syncytium containing many nuclei. The ground-substance appears in spaces between the cells as an albuminous fluid. Later, granules are deposited in the ground-substance by the activity of the cells, and become fused to form the fibres of the tissue.

CARTILAGE

Cartilage is a non-vascular structure found in various parts of the body—in the joints, parietes of the thorax, trachea, bronchi, nose, and ears. In the foetus.

FIG. 24.—Cartilage cells in the costal cartilage of a kitten. $\times 250$.

Cartilage-cell containing fat



at an early period, the greater part of the skeleton is cartilaginous; as this cartilage is afterwards replaced by bone, it is called *temporary*, in contradistinction to that which remains unossified during the whole of life and is called *permanent*.

Cartilage is divided, according to its minute structure, into *hyaline cartilage*, *white fibrocartilage*, and *yellow* or *elastic fibrocartilage*. Besides these varieties met with in the adult human subject, there is a variety called *cellular cartilage*, formed entirely, or almost entirely, of cells, separated from each other by their capsules only, which in this kind of cartilage are extremely well marked. Cellular cartilage is found in the external ears of rats, mice, and some other animals, and it also forms a stage in the development of cartilage in human embryonic life.

Hyaline cartilage has a pearly bluish colour and consists of a gristly mass of a firm consistence, but of considerable elasticity. Except where it coats the articular

ends of bones, it is covered by a fibrous membrane, the *perichondrium*, from the vessels of which it imbibes its nutritive fluids, being itself destitute of blood-vessels. It contains no nerves. If a thin slice be examined under the microscope, it will be found to consist of cells of a rounded or bluntly angular form, lying in spaces in a granular or almost homogeneous matrix (fig. 24). The cells are frequently arranged in groups of two or more, and, when this is the case, they have generally straight outlines where they are in contact with each other, but are rounded in the rest of their circumference. They consist of clear translucent protoplasm in which fine interlacing filaments and minute granules are sometimes present; imbedded in the protoplasm are one or two round nuclei, having the usual intranuclear network.

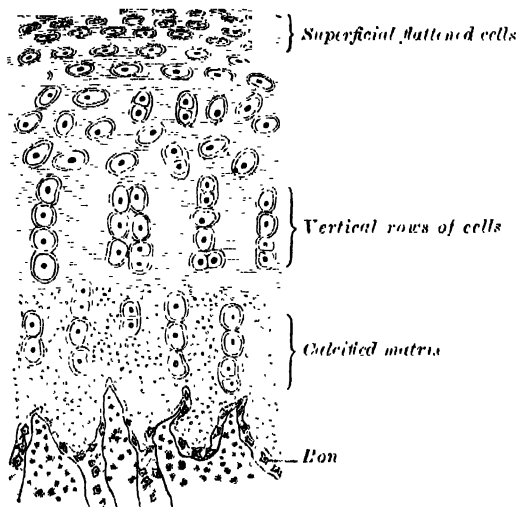
The matrix is transparent and apparently without structure, or else presents a dimly granular appearance, like ground glass. The portion immediately surrounding each cell-space is often well defined, and is further characterised by its affinity for basic dyes. It is known as the *capsule* of the space. The matrix of hyaline cartilage, and especially that of the articular variety, can be broken up into fine fibrils after prolonged maceration. These fibrils are probably of the same nature, chemically, as the white fibres of connective tissue. It is believed by some histologists that the matrix is permeated by a number of fine channels, which connect the cell-spaces with each other and with the lymphatics of the perichondrium, and that in this way nutrient fluid obtains access to the cartilage-cells.

Articular cartilage, costal cartilage, and temporary cartilage are all of the hyaline variety, but they present differences in the size, shape, and arrangement of their cells.

Articular Cartilage (fig. 25) shows no tendency to ossification; its matrix is finely granular, and its cells are flattened and disposed parallel to the surface in the superficial part of the cartilage, while nearer to the bone they are oval and are arranged in vertical rows. It has a tendency to split in a vertical direction. Its free surface is not covered by perichondrium, but the synovial stratum of the articular capsule can be traced over a small part of its circumference, and here the cartilage-cells are more or less branched and pass insensibly into the branched connective tissue cells of the synovial stratum. It forms a thin layer upon the joint-surfaces of the bones, and its elasticity enables it to break the force of concussions, while its smoothness affords ease and freedom of movement. It varies in thickness according to the shape of the articular surface on which it lies; where this is convex the cartilage is thickest at the centre, the reverse being the case on concave articular surfaces. It appears to derive its nutriment partly from the vessels of the synovial stratum of the joint-capsule and partly from those of the bone upon which it is implanted. The minute vessels of the spongy bone dilate and form arches as they approach the articular lamella, and then return into the substance of the bone.

In **costal cartilage** the cells and nuclei are large, and the matrix, which is usually homogeneous and transparent, has a tendency to fibrous striation, especially in old age (fig. 26). In the thickest parts of the costal cartilages a few large vascular channels may be detected. This appears, at first sight, to be an exception to the statement that cartilage is non-vascular, but is not so really, for the vessels give no branches to the cartilage itself, and the channels may rather be looked upon as involutions of the perichondrium. The xiphoid process of the sternum and the cartilages of the nose, larynx, and trachea (except the epiglottis and corniculate

FIG. 25.—Vertical section of articular cartilage.

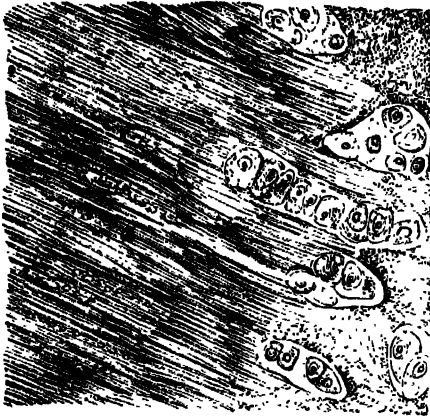


cartilages of the larynx, which are composed of elastic fibrocartilage) resemble the costal cartilages in microscopical characteristics. The arytenoid cartilage of the larynx shows a transition from hyaline cartilage at its base to elastic cartilage at the apex.

The hyaline cartilages, especially in adult and advanced life, are prone to calcify—that is to say, their matrix becomes permeated by calcium salts. Calcification

occurs frequently in the costal cartilages, and in the cartilages of the trachea, and may be succeeded by ossification.

FIG. 26.—Costal cartilage from a man seventy-six years of age, showing the development of fibrous structure in the matrix. In several portions of the specimen two or three generations of cells are seen enclosed in a parent cell-wall. Highly magnified.

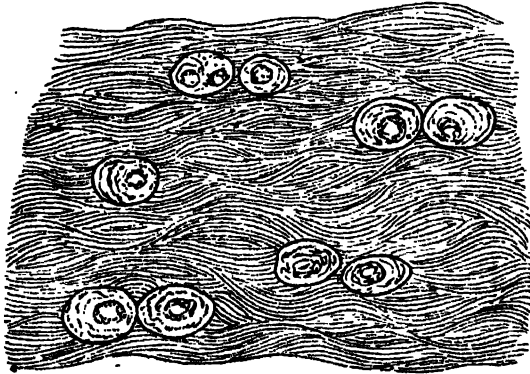


White fibrocartilage consists of fibrous connective tissue arranged in bundles, with cartilage-cells between the bundles; the cells are roughly ovoid in shape, and are surrounded by concentrically striated areas of cartilage-matrix (fig. 27). The white fibrocartilages admit of arrangement into four groups—interarticular, connecting, circumferential, and stratiform.

1. The *interarticular fibrocartilages* (*menisci*) are flattened fibrocartilaginous plates, of a round, oval, triangular, or sickle-like form, interposed between the articular cartilages of certain joints; the synovial stratum of the articular capsule covers their free surfaces. They are found in the temporomandibular, sternoclavicular, acromioclavicular, wrist- and knee-joints. Their uses are to obliterate the intervals between opposed surfaces in their various motions; to increase the depths of the articular surfaces and give ease to the gliding movements; they also increase the varieties of movement in a joint.

2. The *connecting fibrocartilages* are interposed between the bony surfaces of those joints which admit of only slight mobility, as between the bodies of the vertebrae. They form discs which are closely adherent to the opposed surfaces.

FIG. 27.—White fibrocartilage from an intervertebral fibrocartilage.



Each disc is composed of concentric layers of fibrous tissue, with cartilaginous laminae interposed, the former tissue predominating towards the circumference, the latter towards the centre.

3. The *circumferential fibrocartilages* consist of rims of fibrocartilage, which surround the margins of some of the articular cavities, e.g. the glenoidal labrum of the hip-joint and that of the shoulder-joint; they serve to deepen the articular cavities and to protect their edges.

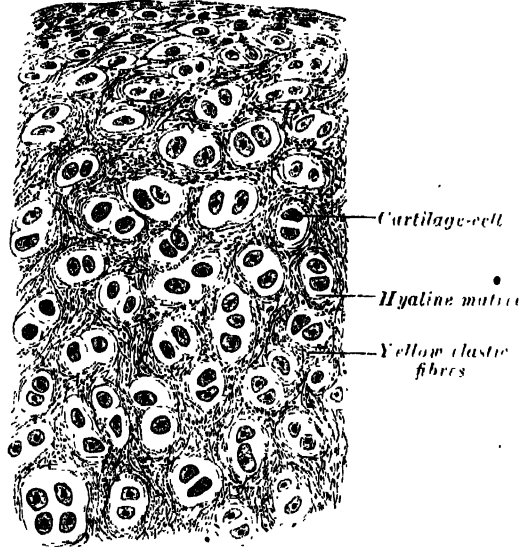
4. The *stratiform fibrocartilages* form thin coatings to osseous grooves through which the tendons of certain muscles glide.

Small masses of fibrocartilage are also developed in the tendons of some muscles, where they glide over bones, as in the tendons of the *Peronæus longus* and *Tibialis posterior*.

Yellow or elastic fibrocartilage is found in the ears, the corniculate cartilages of the larynx, and the epiglottis. It consists of cartilage-cells and a matrix, the latter being pervaded by a network of yellow elastic fibres, branching and anastomosing in all directions, except immediately around the cells, where there is a variable amount of hyaline substance (fig. 28). The fibres resemble those of yellow elastic tissue, not only in appearance, and in being unaffected by acetic acid, but also in their affinity for orcein; according to Rollett their continuity with the elastic fibres of the neighbouring tissue is demonstrable.

The distinguishing feature of cartilage, chemically, is that it yields on boiling a substance called *chondrin*, a mixture of gelatin with mucinoid substances chief among which is a compound termed *chondromucoid*.

FIG. 28.—Yellow or elastic fibrocartilage from the epiglottis of a cat. 250.



BONE

Structure and physical properties.—Bone is one of the hardest structures of the animal body; it possesses also a certain degree of toughness and elasticity. Its colour, in a fresh state, is pinkish white externally, and deep red within. On examining a section of a bone, it is seen to be composed of two kinds of tissue, one of which is dense in texture, like ivory, and is termed *substantia compacta*; the other consists of slender fibres and lamellæ, which join to form a reticular structure; this is called *substantia spongiosa* or, from its resemblance to lattice work, *cancellous tissue*. The compact substance is always placed on the exterior of the bone, the spongy in the interior. The relative quantities of these vary in different bones and in different parts of the same bone, according as strength or lightness is requisite. Close examination of the compact substance shows it to be extremely porous, so that the difference between it and the spongy substance depends merely upon the relative amount of solid matter and the size and number of spaces in each; in the compact substance the spaces are small and the solid matter abundant, while in the spongy substance the spaces are large and the solid matter small in quantity.

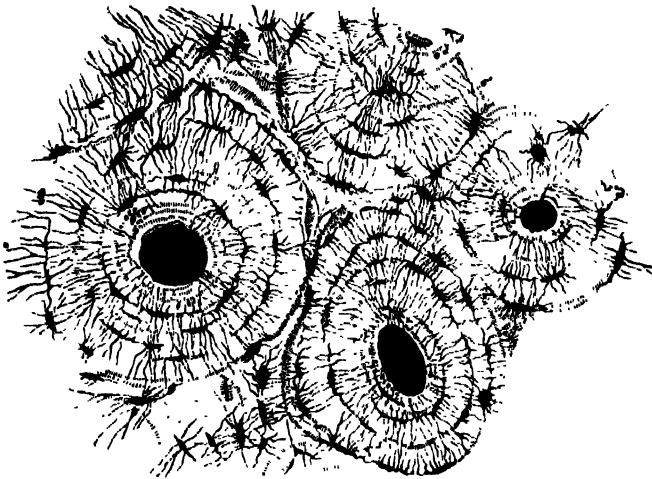
During life, bone is permeated by vessels, and enclosed, except where it is coated with articular cartilage, in a fibrous membrane, the *periosteum*, by means of which many of these vessels reach the bone. If the periosteum be stripped from the surface of the living bone, small bleeding points are seen which mark the entrance of the periosteal vessels; and on section every part of the bone exudes blood from the minute vessels which ramify in it. In the interior of the long bones of the limbs is a cylindrical cavity (*cavum medullare*) filled with *medulla ossium* or *marrow*, and lined by a highly vascular areolar structure, called the *medullary membrane* or *internal periosteum*.

The **periosteum** adheres to the surface of the bones in nearly every part, but not to the cartilage covering their articular surfaces. When strong tendons or

ligaments are attached to a bone, the periosteum is incorporated with them. It consists of two layers closely united together, the outer formed chiefly of white fibrous tissue, containing occasionally a few fat-cells; the inner, of elastic fibres of the finer kind, forming dense membranous networks, which can be again separated into several layers. In young bones the periosteum is thick and very vascular, and is intimately connected at either end of the bone with the epiphysial cartilage, but less closely with the body of the bone, from which it is separated by a layer of soft tissue, containing a number of granular corpuscles or 'osteoblasts,' by which ossification proceeds on the exterior of the young bone. Later in life the periosteum is thinner and less vascular, and the osteoblasts are converted into an epithelioid layer on its deep surface. The periosteum serves as a nidus for the ramification of the vessels previous to their distribution in the bone; hence the liability of bone to exfoliation or necrosis when denuded of this membrane by injury or disease. Fine nerves and lymphatics, which generally accompany the arteries, may also be demonstrated in the periosteum.

The **medulla ossium** or **marrow** not only fills up the cylindrical cavities in the bodies of the long bones, but also occupies the spaces of the cancellous tissue and

FIG. 29.—Transverse section of the compact substance of bone.
Magnified. (Sharpey.)



extends into the larger Haversian canals. It differs in composition in different bones. In the bodies of the long bones the marrow is of a *yellow* colour (*medulla ossium flava*), and consists of a basis of connective tissue supporting numerous blood-vessels and cells, most of which are fat-cells, but some are 'marrow-cells,' such as occur in the red marrow. In the flat and short bones, in the articular ends of the long bones, in the bodies of the vertebræ, in the cranial diploë, and in the sternum and ribs, the marrow is of a *red* colour (*medulla ossium rubra*); it consists of marrow-cells, red and white blood-corpuscles, giant-cells, and a few fat-cells, all supported by a reticulum of connective tissue. In post-natal life the red marrow is the chief seat of formation of the corpuscles of the blood, and it will therefore be described more fully in that connexion (p. 28).

Vessels and nerves of bone.—The *blood-vessels* of bone are very numerous. Those of the compact substance are derived from a close network of vessels in the periosteum. Vessels pass from this network into the minute orifices in the compact substance, and run in the Haversian canals which traverse it. The spongy substance is supplied in a similar way by larger vessels, which perforate the outer compact substance, and are distributed to the cavities of the spongy portion of the bone. In the long bones, numerous apertures may be seen at the ends near the articular surfaces; some of these give passage to arteries; but the greater number transmit veins from the spongy substance. The marrow of a long bone is supplied by an artery which enters the bone at the nutrient foramen (*foramen*

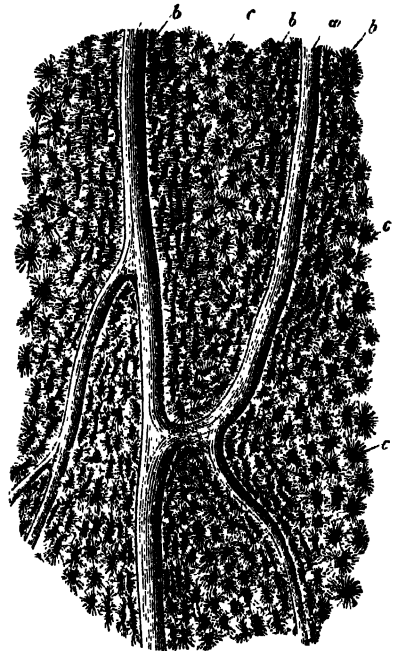
nutricium). The *nutrient* artery, usually accompanied by one or two veins, sends branches upwards and downwards, which ramify in the medullary membrane, and give twigs to the adjoining Haversian canals. The ramifications of this vessel anastomose with the arteries of the spongy and compact substances. In most of the flat, and in many of the short bones there are one or more large apertures for the transmission of nutrient vessels. Veins emerge from the long bones as follows:—(1) one or two accompany the nutrient artery; (2) numerous large and small veins emerge near the articular extremities; (3) many small veins pass out of the compact substance. In the flat cranial bones the veins are large and run in tortuous canals in the diploic tissue, the walls of the canals being formed by thin lamellæ of bone, perforated here and there for the passage of branches from the adjacent diploë. The same condition is found in all spongy substance, the veins being enclosed and supported by osseous material, and having exceedingly thin coats. When a bone is divided, the vessels remain open, and do not contract in the canals in which they are contained. *Lymphatic vessels*, which communicate with those in the periosteum, are found in the Haversian canals. *Nerves* are distributed freely to the periosteum, and accompany the nutrient arteries into the interior of the bone. They are said to be most numerous in the articular extremities of the long bones, in the vertebrae, and in the larger flat bones.

Minute anatomy.—If a thin transverse section of dense bone be examined with a low power of the microscope it will be seen to be mapped out into a number of circular districts, each consisting of a central hole surrounded by a number of concentric rings. These districts are termed *Haversian systems*; the central hole is a *Haversian canal*, and the rings are *lamellæ* of bony tissue arranged concentrically around the central canal. Between these lamellæ are a number of small spaces termed *lacunæ*, which are connected with each other and with the central Haversian canal by many fine radiating channels called *canaliculi*. Filling in the irregular intervals between these circular districts are *interstitial lamellæ*, with their *lacunæ* and *canaliculi*, running in various directions, but more or less curved (fig. 29). Again, other lamellæ, found on the surface of the bone, are arranged parallel to its circumference; they are termed *circumferential* or *primary* lamellæ, to distinguish them from those surrounding the Haversian canals, which are termed *secondary* lamellæ.

In a longitudinal section it will be seen that the Haversian canals run parallel with the long axis of the bone for a short distance and then branch and communicate (fig. 30). They vary considerably in size, but their average diameter is about 0.05 mm. The canals near the medullary cavity are larger than those near the surface of the bone. Each canal usually contains a minute artery and vein, a small quantity of delicate connective tissue, and some nerve-filaments; in the larger ones there are also lymphatic vessels, and cells with branching processes.

The *lamellæ* are thin plates of bony tissue. They may be stripped off as thin films from a piece of bone which has been macerated in dilute mineral acid. If one of these films be examined with a high power of the microscope, it will be found to be composed of fine fibres identical with those of white connective tissue. The matrix between the fibres is impregnated with lime-salts which the acid dissolves. The fibres of one lamella are connected by branches with those of adjacent lamellæ. Moreover, the fibres of one lamella usually form an acute

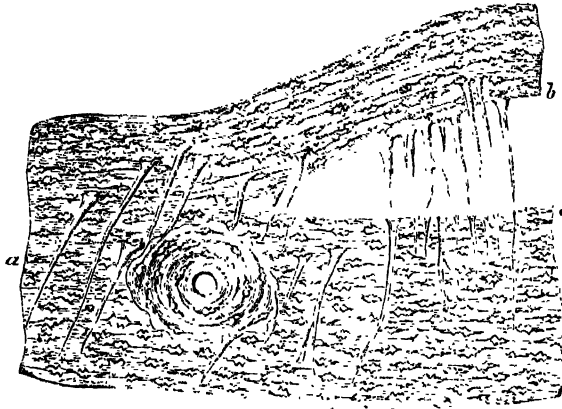
FIG. 30.—Section parallel to the surface from the body of the femur. $\times 100$.



a. Haversian canals. b. Lacunæ seen from the side. c. Others seen from the surface in lamellæ which are cut horizontally.

angle with those of the contiguous layer; in the Haversian systems, however, the fibres of adjacent lamellæ run at right angles to each other. In many places the various lamellæ are held together by tapering fibres, which run obliquely through them, pinning or bolting them together; these fibres were first described by Sharpey, and were named by him *perforating fibres* (fig. 31).

FIG. 31.—Perforating fibres; human parietal bone, decalcified. (H. Müller.) (From Quain's Elements of Anatomy, vol. ii., pt. i., Microscopic Anatomy.)

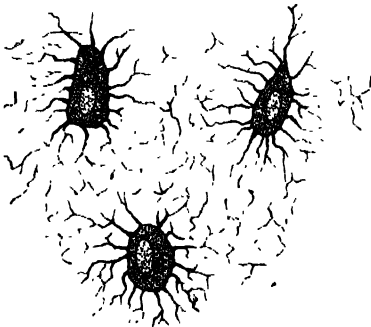


a. Perforating fibres in situ; b. Fibres drawn out of their sockets, c. Sockets.

The *lacunæ* are oblong spaces situated between the lamellæ, and each lacuna is occupied during life by a branched *bone-cell* (fig. 32), the processes from which extend into the canaliculi.

The *canaliculi* are minute channels, crossing the lamellæ and connecting the lacunæ of a Haversian system with one another, and with the Haversian canal. The canaliculi at the periphery of a Haversian system do not as a rule communicate

FIG. 32.—Nucleated bone-cells and their processes, contained in the bone-lacunæ and their canaliculi respectively. From a section through the vertebra of an adult mouse. (Klein and Noble Smith.)



with those of neighbouring systems, but form loops and return to their own lacunæ. Thus every part of a Haversian system is supplied with nutrient fluids derived from the vessels in the Haversian canal and distributed through the canaliculi and lacunæ.

The *bone-cells* occupy, but do not fill, the lacunæ. They are flattened nucleated branched cells, homologous with the lamellar cells of connective tissue; their branches pass into the canaliculi.

In thin plates of bone Haversian canals are absent.

Chemical composition. Bone consists of an animal and an earthy part intimately combined together.

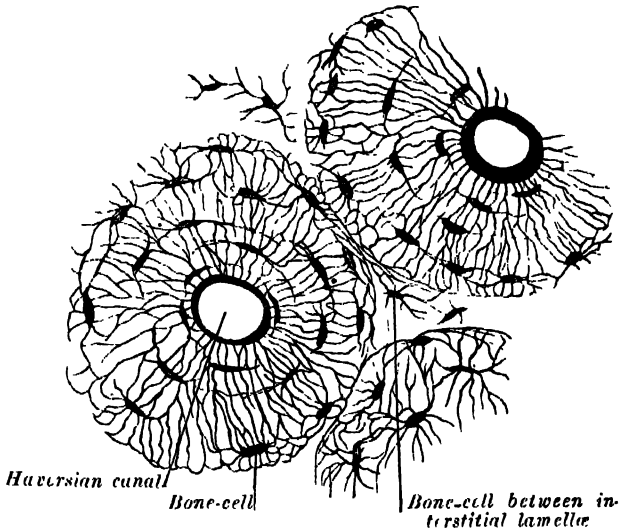
The animal part may be obtained by immersing a bone for a considerable time in dilute mineral acid, which will dissolve the mineral matter. The bone retains

its shape, but is now perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied in a knot. In a transverse section of such a softened bone (fig. 33), the arrangement of the Haversian canals, lamellæ, lacunæ, and canaliculi can be recognised.

The earthy part may be obtained by calcination, which destroys the animal matter. The bone retains its original form, but is white and brittle, has lost about one-third of its original weight, and crumbles under the slightest force. The earthy matter, composed chiefly of calcium phosphate, forms about 66·7 per

cent. of the weight of the bone ; it confers on bone its hardness and rigidity, while the animal matter (*ossein*) determines its resiliency and tenacity.

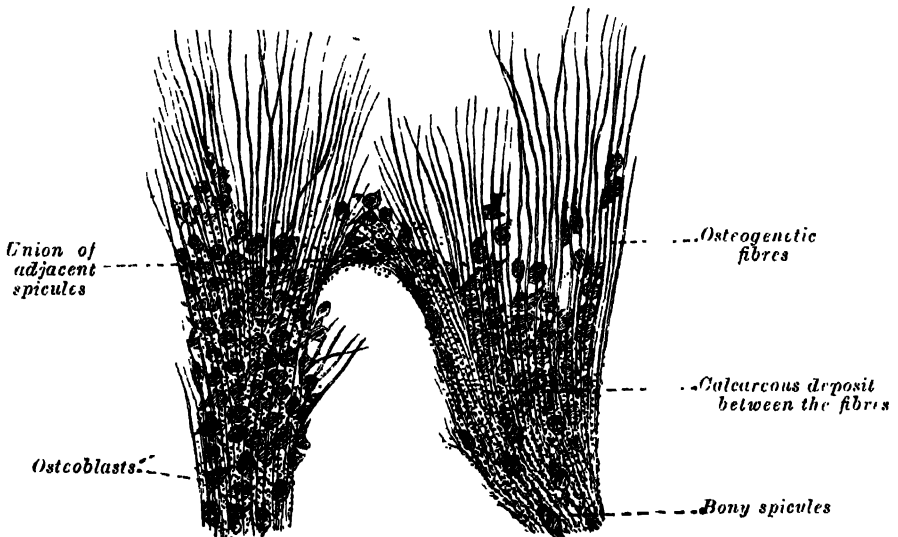
FIG. 33.—Transverse section of the body of a human fibula, decalcified. $\times 250$.



Ossification.—Some bones, such as those of the roof and sides of the skull, are preceded by membrane, but most bones are preceded by rods or masses of cartilage. Hence two kinds of ossification are described ; the *intramembranous* and the *intracartilaginous*.

Intramembranous ossification.—The membrane which occupies the place of the future bone is of the nature of connective tissue, and ultimately forms the

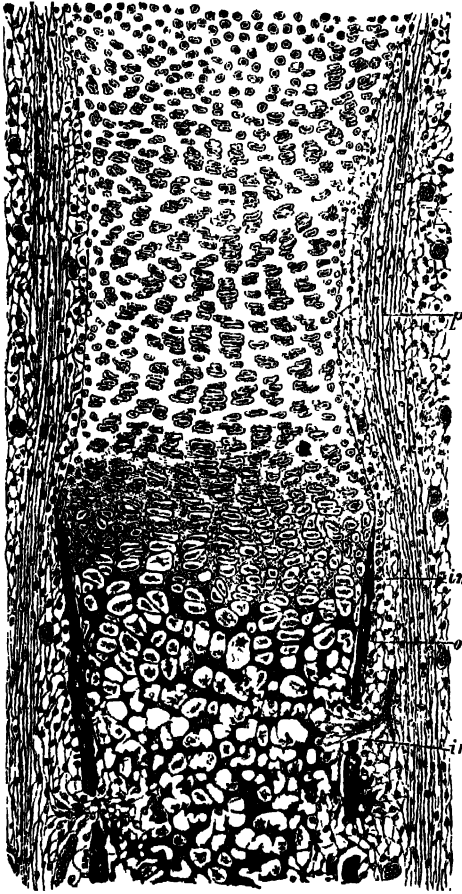
FIG. 34.—Part of the growing edge of the developing parietal bone of a fetal cat. (After J. Lawrence.)



periosteum ; it is composed of fibres and granular cells in a matrix richly supplied with blood-vessels. The peripheral portion is more fibrous, while in the central portion the cells or *osteoblasts* predominate. At the outset of the process of bone formation a little network of fibres radiates from the centre of ossification. These rays consist at their growing points of a network of fine clear fibres and granular corpuscles with an intervening ground-substance (fig. 34). The fibres are termed

osteogenetic fibres, and differ little from those of white fibrous tissue. The membrane assumes a dark and granular appearance from the deposition of calcareous granules in the matrix between the fibres, and in the calcified material some of the granular cells or osteoblasts are enclosed. By the fusion of the calcareous granules the tissue again assumes a more transparent appearance, but the fibres are no longer so distinctly seen. The osteoblasts form the bone-cells of the future bone, the spaces in which they are enclosed constituting the lacunæ. As this process advances, a network of bone is formed, the meshes of which contain the blood-vessels and a

FIG. 35.—Section of a fetal bone of a cat.
(From Quain's Anatomy.)



im. Subperiosteal bony deposit. *ir.* Irruption of the subperiosteal tissue. *o.* Layer of osteoblasts. *p.* Fibrous layer of the periosteum.

delicate connective tissue crowded with osteoblasts. The bony trabeculae thicken by the addition of fresh layers formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently the bone increases in thickness by the deposition of successive layers under the periosteum and round the larger vascular channels which become the Haversian canals.

Intracartilaginous ossification.—

Most of the bones are ossified in cartilage. In a long bone, which may be taken as an example, the process commences in the centre and proceeds towards the extremities, which for some time remain cartilaginous. Subsequently a similar process commences at one or more centres in the extremities, and gradually extends through them. The ossified extremities do not, however, fuse with the body of the bone until growth has ceased; between the body and either extremity a plate of cartilage termed the *epiphysial cartilage* persists for a time.

At the centre of ossification, or point where the ossifying process begins, the cartilage-cells multiply and enlarge and arrange themselves in rows (fig. 35). The matrix in which they are imbedded increases in quantity, so that the cells are further separated from each other.

A deposit of calcareous material now takes place in this matrix, so that it presents a granular and opaque appearance. The cartilage-

cells are enclosed in oblong cavities, the walls of which are formed of calcified matrix which cuts off all nutrition from the cells; the cells, in consequence, atrophy, leaving spaces called the *primary areolæ*.

While this process is going on in the centre of the bar of cartilage, certain changes are taking place on its surface. This is covered by a very vascular membrane, the *perichondrium*, formed of connective tissue similar to that already described as constituting the basis of membrane-bone; on the inner surface of this—that is to say, on the surface in contact with the cartilage—are gathered the formative cells, the *osteoblasts*. By the agency of these cells a thin layer of bony tissue is laid down, between the perichondrium and the cartilage, by the *intramembranous* mode of ossification just described. There are then, in this first stage, two processes going on simultaneously: in the centre of the cartilage the formation of a number of oblong spaces, bounded by calcified matrix and containing the withered cartilage-

cells, and on the surface of the cartilage the formation of a layer of true membrane-bone. The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium (now periosteum) (fig. 35, *iv*). The processes consist of blood-vessels and cells—*osteoblasts*, or bone-formers, and *osteoclasts*, or bone-destroyers. The latter are large, multinucleated protoplasmic masses, and they excavate passages through the new-formed bony layer by absorption, and pass through it into the calcified matrix (fig. 36). Wherever these processes of the osteogenetic layer come in contact with the calcified walls of the primary areolæ they absorb them, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the *secondary areolæ* or *medullary spaces*. These secondary spaces are filled with embryonic marrow, consisting of osteoblasts and vessels, derived, in the manner described above, from the osteogenetic layer of the periosteum (fig. 36).

The walls of the secondary areolæ increase in thickness by the deposition of layers of bone on their surface. This process takes place in the following manner. Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as a layer on the surface of the wall of the space (fig. 36). This layer of osteoblasts forms a bony stratum, which gradually covers the wall of the space and in which some of the osteoblasts are included as bone cells. The next stage in the process consists in the removal of these primary bone spicules by the osteoclasts, one of which may be seen lying in a Howship's foveola at the free end of each spicule (fig. 37). The removal of the primary spicules goes on *pari passu* with the formation of permanent bone by the periosteum, and in this way the medullary cavity of the bone is formed.

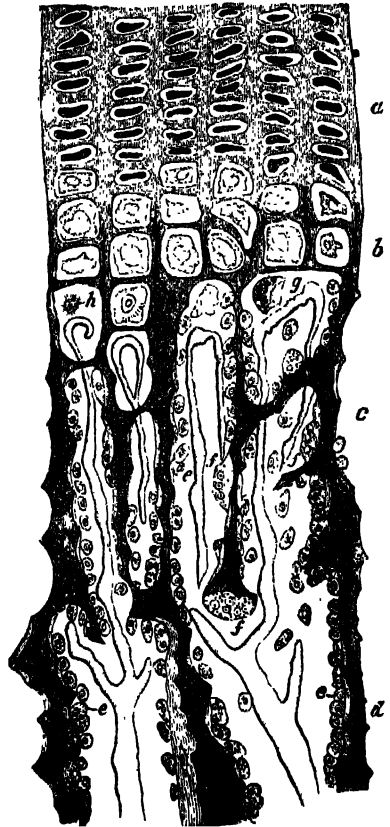
This series of changes proceeds gradually towards the ends of the bone, so that all the changes described above may be seen in different parts, from the true bone at the centre of the body to the hyaline cartilage at the extremities.

While the ossification of the cartilaginous body is extending towards the articular ends, the cartilage immediately in advance of the osseous tissue continues to grow until the length of the adult bone is reached.

The articular end remains for some time cartilaginous, and then one or more bony centres, or epiphyses, appear, and initiate in it the process of ossification; but the extremity remains separated from the body of the bone by a narrow cartilaginous layer, the *epiphysial cartilage*, for a definite time. This cartilage ultimately ossifies, and the bone assumes its completed form and shape. The same remark applies to such processes of bone as are ossified from separate epiphyses, e.g. the trochanters of the femur. Bones increase in length by ossification continuing to extend into the epiphysial cartilage, which goes on growing in advance of the ossifying process. They increase in circumference by deposition of new bone, from the deep layer of the periosteum, on their external surfaces, and at the same time an absorption takes place from within, by which the medullary cavities are increased.

The permanent bone formed by the periosteum when first laid down is spongy in structure. Later the osteoblasts contained in its spaces form the concentric layers characteristic of the Haversian systems, and are included as bone-cells.

FIG. 36.—Part of a longitudinal section of the developing femur of a rabbit. (Klein and Noble Smith.)



Flattened cartilage-cells. *b*. Enlarged cartilage-cells. *c*, *d*. Newly formed bone. *e*. Osteoblasts. *f*. Giant-cells or osteoclasts. *g*, *h*. Shrunken cartilage-cells.

The number of ossific centres varies in different bones. Most of the short bones are ossified from a single centre. In the long bones there is a primary centre for the body, or diaphysis; and one or more secondary centres, or epiphyses, for each extremity. That for the body is the first to appear. The times of union of the epiphyses with the body vary inversely with the dates at which their ossifications

FIG. 37.—Osteoblasts and osteoclasts in the developing femur of a kitten. $\times 350$.



begin (with the exception of the fibula) and regulate the direction of the nutrient arteries of the bones. Thus, the nutrient arteries of the bones of the arm and forearm are directed towards the elbow, since the epiphyses at this joint become united with the bodies of the bones before those at the opposite extremities. In the lower limb, on the contrary, the nutrient arteries are directed away from the knee; that is, upwards in the femur, downwards in the tibia and fibula; and in them it is observed that the epiphyses at the upper end of the femur, and those at the lower ends of the tibia and fibula, unite first with the bodies. Where there is only one epiphysis, the nutrient artery is directed towards the other end of the bone.

Parsons* groups epiphyses under three headings, viz. (1) *pressure epiphyses*, appearing at the articular ends of the bones and transmitting 'the weight of the body from bone to bone'; (2) *traction epiphyses*, associated with the insertion of muscles and 'originally sesamoid structures though not necessarily sesamoid bones'; and (3) *atavistic epiphyses*, representing parts of the skeleton which at one time formed separate bones, but which have lost their function 'and only appear as separate ossifications in early life.'

The description here given of the development and growth of bone is in accordance with the generally accepted view. Macewen† has, however, given another account. He asserts that the osteoblasts are produced by division of the nuclei of the cartilage-cells, and that bone-formation is brought about by these cells, the periosteum taking no part in the process. He concludes that the function of the periosteum in the development of bone is mechanical, and is confined to limiting the degree of growth and deciding its direction.

Applied Anatomy.—It has been stated above that the bones increase firstly in length by ossification continuing to extend in the epiphysal cartilage, which goes on growing in advance of the ossifying process; and secondly in circumference by deposition of new bone from the deeper layer of the periosteum, on the external surface.

A careful study of osseous development is of the very greatest utility in the proper understanding of bone disease; and, moreover, an accurate knowledge of the blood-supply of a long bone has also many important bearings. The outer portion of the compact tissue being supplied by periosteal vessels which reach the bone through muscular attachments, it follows that where the muscular structures are well developed, and therefore amply supplied with blood, the periosteum will also be well nourished and the bones proportionately well developed in girth; this is well seen in strong muscular men with well-marked ridges on the bones. Conversely, if the muscular development be poor, the bones are correspondingly thin and light, and if from any cause a limb has been paralyzed

* *Journal of Anatomy and Physiology*, vols. xxxviii., xxxix., and xlii.

† *The growth of bone*, by Sir William Macewen.

from early childhood, the whole of the bones of that extremity are remarkable for their extreme thinness—that is to say, the periosteal blood supply has been insufficient to nourish that membrane, and consequently very little fresh osseous tissue has been added to the bones from the outside.

The best example of this condition is seen in connexion with the disease known as *infantile paralysis*, where a limb becomes paralyzed at a very early period of childhood, where the muscles become flaccid and atonic, and where the blood-supply is in consequence very greatly diminished. In such cases, although the limb does continue to grow in length from the epiphysal lines, its length is considerably less than on the normal side, owing to the imperfect nutrition; but the most striking feature about all the long bones of the limb is their remarkable tenuity, little or no addition having been made to their circumferences.

In cases where the periosteum has been separated from the compact tissue by extensive injury or inflammatory exudation, necrosis or death of the underlying portion of bone takes place owing to its blood-supply having been cut off, and the dead portion or *sequestrum* has to be separated.

Cases, however, occur where the inflammatory process affects the whole or a great portion of the diaphysis of a long bone; here extensive death of the affected portion takes place, and the condition goes by the name of *acute infective periostitis*. Where this occurs the body of the bone dies very rapidly, especially if the single nutrient artery be thrombosed at the same time. The pus which has formed beneath the periosteum is set free by timely incision, or bursts on the surface; the periosteum then falls back on the necrosed diaphysis and rapidly forms a layer of new periosteal bone, surrounding the sequestrum. This layer is called the *involucrum*, and the openings in it through which the pus escapes the *cloaca*. When the inflammatory process affects mainly the medullary canal, the condition is spoken of as *osteomyelitis*, and the two conditions very frequently coexist, and then go by the name of *acute infective necrosis of bone* or *acute diaphysitis*. When the medullary cavity is filled with pus, septic thrombosis of the veins in the Haversian canals takes place, and there is a very great danger of septic emboli being displaced and carried into the general circulation, thus setting up a fatal *pyæmia*. In fact, *pyæmia* is more frequently due to septic bone conditions than to any other cause.

In pre-antiseptic days, *pyæmia* frequently resulted from amputations, where the medullary canal of a long bone was opened by the saw cut. *Osteomyelitis* ensued, and if the patient survived, a tubular sequestrum of the divided shaft subsequently separated.

A proper knowledge of the epiphyses is of the utmost possible importance, and greatly simplifies many of the problems in the pathology of bone disease.

Speaking generally, the long bones have at either end an epiphysis from the cartilage of which growth occurs, and hence the body of the bone increases in length from both ends. In every case, however, one epiphysis is the more active, and also continues in its activity for a longer time. This *actively growing epiphysis* is always the one from which the nutrient foramen in the diaphysis points, and it unites to the diaphysis at a later date. It follows, therefore, that the increase in length of a bone is largely dependent on this epiphysis, and hence anything which interferes with the growth from this epiphysal line at any time prior to the union of the epiphysis with the diaphysis must result in a cessation of growth in length of that bone. Thus when dealing with disease in the neighbourhood of this actively growing epiphysis very great care should be taken not to excise or destroy its line of union with the diaphysis. These epiphyses are particularly prone to become the seat of tuberculous disease, which tends to attack especially the soft, highly vascular cancellous tissue.

Again, the actively growing epiphysal plate is the portion of a long bone which is in the vast majority of cases affected by tumour growth in bone, whether it be innocent or malignant, the former (e.g. *osteoma*) usually appearing about puberty, and the latter (e.g. *sarcoma*) usually towards the end of the active period of epiphysal growth.

Epiphysal growth, moreover, has to be considered by the surgeon when he is about to amputate in a child. If the amputation is being performed through a bone, the actively growing epiphysis of which is at the upper end (e.g. humerus and tibia), and which will continue to grow for several years, it will be necessary to make allowance for this and to cut the flaps long; as otherwise, owing to continued growth, the sawn end of the bone will ultimately project through the stump, and result in a condition known as '*conical stump*.' This requires removal of a further portion of the bone.

Premature synostosis or ossification at the epiphyses of the long bones, bringing to an end the process by which they normally increase in length, is one of the causes of dwarfism. Persons in whom this has occurred will have the head and trunk of normal size, but the legs and arms disproportionately short though often very stout and strong.

An inflammatory condition termed *acute epiphysitis* also occurs, although it is not so frequent as the acute infective conditions of the diaphysis, owing to the freer blood-supply of the epiphysis; in late years it has been shown that acute epiphysitis in children is very frequently the result of a pneumococcal infection, and it may pass on to complete separation of the epiphysis. In this connexion it is worthy of note that some of the epiphysal lines lie entirely within the capsules of their corresponding joints, in other cases

entirely without the capsules; and it must follow that in the former case the epiphysal disease, acute or chronic, becomes, *ipso facto*, practically synonymous with disease of that joint. The best examples of intraarticular epiphyses are those for the head of the femur and head of the humerus, and the vast majority of all cases of tuberculous disease of the hip start as a tuberculous epiphysitis about the intraarticular epiphysal plate of the femur; again, cases of acute septic arthritis of the shoulder- or hip-joints generally have their origins in these intraarticular epiphysal lines, and often result in separation of the affected epiphysis. Those of the other class, or extraarticular epiphyses, when diseased, do not tend to involve the neighbouring joint so readily; and it should be the surgeon's duty to keep the disease from involving the joint. For example, the trochanteric epiphysis of the femur is extraarticular as regards the hip-joint, and the epiphysal line of the head of the tibia is well below the level of the knee-joint, and should a chronic tuberculous abscess form in the latter situation, it should be attacked from the outside before it has time to spread up and involve the cartilage of the head of the tibia. It is therefore of great surgical interest to note in every case the relations which the various epiphysal lines bear to their respective joint capsules.

A knowledge of the exact periods when the epiphyses become joined to the shaft is often of great importance in medico-legal inquiries. It also aids the surgeon in the diagnosis of many of the injuries to which the joints are liable; for it not infrequently happens that, on the application of severe force to a joint, the epiphysis becomes separated from the diaphysis, and such injuries may be mistaken for fracture or dislocation. Examination with the x-rays is naturally of the greatest service in deciding whether epiphyses have or have not united, and whether they have been cracked or displaced by injury. •

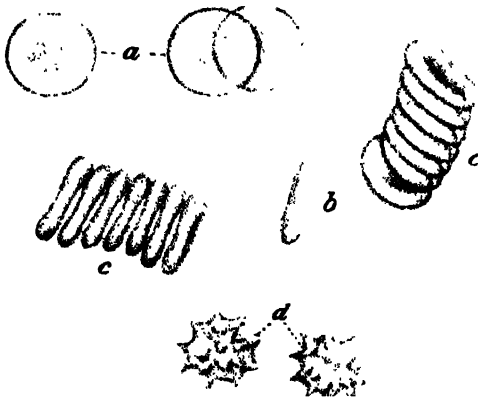
THE CIRCULATING FLUIDS

The **circulating fluids** of the body are the blood and the lymph.

BLOOD

The blood is an opaque, rather viscid fluid, of a bright red or scarlet colour when it flows from the arteries, of a dark red or purple colour when it flows from the veins. It is salt to the taste, and has a peculiar faint odour and an alkaline reaction. Its specific gravity is about 1.059, and its temperature is generally about 37° C., though varying slightly in different parts of the body.

FIG. 38.—Human red blood-corpuscle 1500.



a. Seen from the surface. b. Seen in profile. c. Forming rouleaux
d. Rendered crenate by salt solution.

If a thin film of blood be examined under the microscope it is seen to consist of a faintly yellow fluid, the *plasma* or *liquor sanguinis*, in which are suspended numerous minute particles, the *blood-corpuscles*.

The **blood-corpuscles** are of three kinds: (1) coloured corpuscles or erythrocytes, (2) colourless corpuscles or leucocytes, (3) blood-platelets.

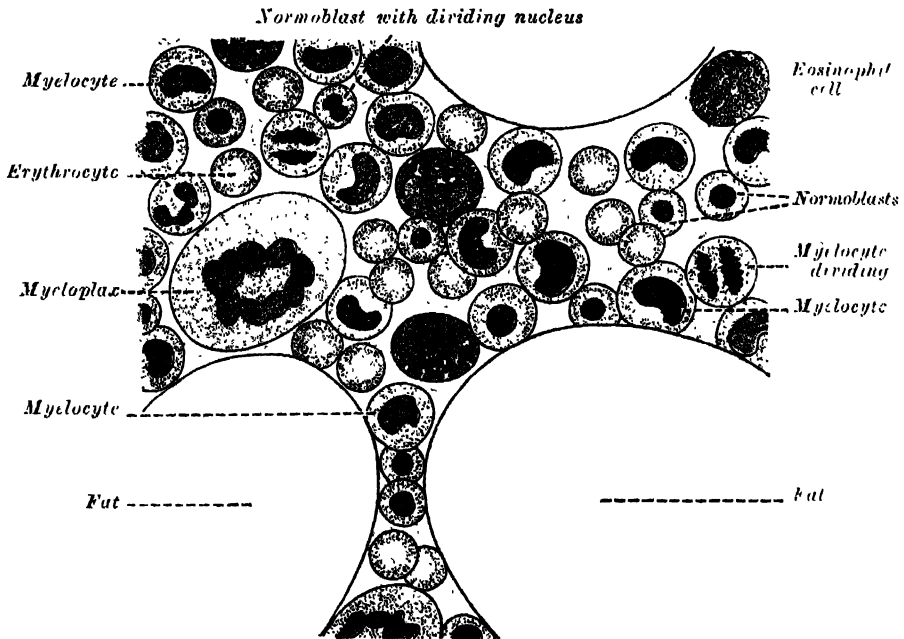
1. **Coloured or red corpuscles (erythrocytes)** are circular discs, biconcave in profile. The disc has no nucleus, but, in consequence of its biconcave shape, it presents, when seen on the flat, a central area which, when the more prominent peripheral zone of the

corpuscle is in focus, appears dark, and so simulates a nucleus (fig. 38, a). The corpuscles vary slightly in size even in the same drop of blood, but the average diameter of each is about 7.5 μ , and the thickness about 2 μ . Besides these there are certain smaller corpuscles of about one-half of the size just indicated; these are termed *microcytes*, and are very scarce in normal blood; in diseased conditions (e.g. anæmia), however, they are more numerous. It is to the aggregation of the red corpuscles that the blood owes its red hue, although when examined by

transmitted light their colour appears to be only a faint reddish yellow. The number of red corpuscles in a cubic millimetre of blood is about 5,000,000 in a man, and 4,500,000 in a woman. Power states that the red corpuscles of an adult would present an aggregate surface of about 3,000 square yards.

If the web of a living frog's foot be spread out and examined under the microscope, the blood is seen to flow in a continuous stream through the vessels, and the corpuscles show no tendency to adhere to each other or to the wall of the vessel. Doubtless the same is the case in the human body; but when human blood is drawn and examined on a slide, the corpuscles tend to collect into heaps like rouleaux of coins (fig. 38, c). During life the red corpuscles may be seen to change their shape under pressure so as to adapt themselves, to some extent, to the size of the vessel. They are, however, highly elastic, and speedily recover their shape when the pressure is removed. They are readily influenced by the medium in which they are placed. In 0.9 per cent. sodium chloride solution, which is isotonic with human blood-plasma, they are unaltered in shape. In hypotonic solutions they swell up and become globular owing to the passage of water from the surrounding

FIG. 39.—Human bone-marrow. Highly magnified.



medium into the corpuscle (*endosmosis*). In hypertonic solutions, e.g. 2 per cent. sodium chloride, water passes in the reverse direction (*exosmosis*) and the corpuscle shrinks and becomes crenated in appearance (fig. 38, d). The surface layer of the erythrocyte thus behaves as a membrane which is permeable to water, but not to salts (semi-permeable membrane), and, for this and other reasons, Schäfer believes that each corpuscle consists of an envelope containing the coloured substance, hæmoglobin. According to another view, the erythrocyte consists of a stroma or sponge work permeated by the hæmoglobin. The stroma, or envelope consists mainly of cholesterol, lecithin, and nucleoprotein.

The origin of the red corpuscles.—(1) In *early embryonic life* nucleated erythrocytes (*erythroblasts*) are formed in the 'blood-islands' of the vascular area. Certain mesodermic cells in these islands enlarge, and the nucleus of each subdivides, forming a number of daughter nuclei. The interior of the cell then becomes hollowed out, so that the nuclei, each surrounded by a certain amount of protoplasm, lie free in a fluid. The protoplasm of most of these nucleated fragments, which are known as *hæmoblasts*, becomes tinged with hæmoglobin, and in this way the erythroblasts are formed. By the fusion of adjacent hollowed cells and the intercommunication of the cavities containing the erythroblasts the blood-vessels are formed. After the appearance of the liver and spleen multiplication

of the nucleated blood-corpuscles goes on by mitotic division in the vascular spaces of these organs, as well as in the circulating blood itself. Ultimately the nuclei of the erythroblasts disappear, probably by atrophy, and in the eighth month of foetal life the red corpuscles are nearly all non-nucleated. (2) In *later embryonic life* the formation of non-nucleated erythrocytes takes place in the cells of the connective tissue. Coloured globules appear in the body of the cell, and are set free by the vacuolation of the cell substance around them, the vacuoles becoming fused so that the globules float in a fluid. Blood-vessels are formed by the union of adjacent cells, as in the mesoderm at an earlier period. (3) During *post-natal life* the formation of erythrocytes occurs in the red marrow of bones. The red marrow consists of a small quantity of connective tissue, blood-vessels, and numerous cells (fig. 39), a few of which are fat-cells, but the great majority are spherical, nucleated cells, the true 'marrow-cells.' These marrow-cells proper, or *myelocytes*, resemble the leucocytes of blood, and like them are amoeboid; they contain granules, either oxyphil, basiphil, or neutrophil in reaction. A number of eosinophil cells and a few basiphil cells are also present (see below). Among the marrow-cells may be seen smaller nucleated cells of a yellowish colour; these are the erythroblasts or *normoblasts* from which the red corpuscles are derived, and which may be regarded as descendants of the coloured nucleated corpuscles of the embryo. Erythrocytes are formed from these erythroblasts by the disappearance of the nucleus. Giant-cells (*myeloplaxes* or *megakaryocytes*) similar to the osteoclasts described in connexion with the development of bone, are also found in red marrow.

The **colourless corpuscles** or *leucocytes* are of various sizes. In human blood the majority are rather larger than the red corpuscles, and measure about 10μ in diameter. On the average from 7,000 to 12,000 leucocytes are found in each cubic millimetre of blood.

FIG. 40.—Varieties of colourless corpuscles found in human blood. $\times 1500$.



a. Eosinophil corpuscles. b. Polymorphonuclear leucocytes. c. Hyaline cell or macrocyte. d. Lymphocytes.

They consist of minute nucleated masses of protoplasm, and exhibit several varieties, which are differentiated from each other chiefly by the occurrence or non-occurrence of granules in their protoplasm, and by the staining reactions of these granules when present (fig. 40). (1) The most numerous and important are termed *polymorphonuclear* leucocytes; they are irregular in shape in the living condition, are possessed of the power of amoeboid movement, and are characterised by containing nuclei which often consist of two or three parts (multipartite) connected together by fine threads of chromatin. When at rest or dead, they are spherical in shape as a rule. The protoplasm is clear, and contains a number of very fine granules, which stain with acid dyes such as eosin, or with neutral dyes, and are therefore called *oxyphil* or *neutrophil*. They constitute 60 to 70 per cent. of the total number of the colourless corpuscles. (2) A second variety comprises from 1 to 4 per cent. of the leucocytes; they are larger than the previous kind, and are made up of coarsely granular protoplasm, the granules being highly refractile and grouped round single nuclei of horseshoe shape. The granules stain deeply with eosin, and the cells are therefore often termed *eosinophil* corpuscles. (3) The third variety is called the *hyaline* cell or macrocyte. This is usually about the same

size as the eosinophil cell, and, when at rest, is spherical in shape and contains a single round or oval nucleus. The protoplasm is free from granules, but is not quite transparent, having the appearance of ground glass. (4) The fourth kind is designated the *lymphocyte*, because it is identical with the cell derived from the lymph-glands, or other lymphoid tissue. They are the smallest of the leucocytes,

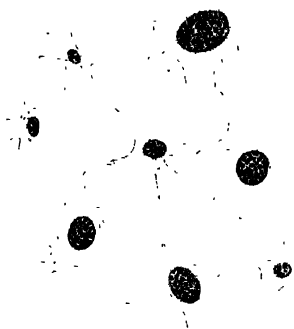
FIG. 41.—Human colourless blood-corpuscle, showing its successive changes of outline within ten minutes when kept moist on a warm stage. (Schiefeld.)



and each consists of a spheroidal nucleus with a very little surrounding protoplasm of a homogeneous nature. The third and fourth varieties together constitute from 20 to 30 per cent. of the colourless corpuscles, but of these two varieties the lymphocytes are by far the more numerous. Leucocytes having in their protoplasm granules which stain with basic dyes (*basophil*) have been described as occurring in human blood, but they are rarely found except in disease.

The colourless corpuscles are very various in shape in living blood (fig. 41), because many of them have the power of constantly changing their form by protruding finger-shaped or filamentous processes of their substance, by which they move and take up granules from the surrounding medium. In locomotion the corpuscle pushes out a process of its substance—a *pseudopodium*, as it is called—and gradually the rest of the body flows into it. In the same way when any granule or particle comes in its way the corpuscle protrudes a pseudopodium towards it, and then draws the particle into its own substance. By means of these amoeboid properties the cells have the power of wandering or emigrating from the blood-vessels by penetrating their walls and thus finding their way into the extravascular spaces. The solid chemical constituents of leucocytes are nucleoprotein, globulin, fat, cholesterol, lecithin, glycogen, and salts.

FIG. 42.—Blood-platelets. Highly magnified. (After Kopsch.) (From Schäfer's Essentials of Histology.)



The origin of the colourless blood-corpuscles.

—In *early embryonic life* leucocytes are developed from the haemoblasts already described. Some of these primitive blood-cells do not become coloured, but are converted into colourless blood-corpuscles. During *post-natal life* the lymphocytes are developed from the cells of lymphoid tissue in the lymph-glands, Malpighian corpuscles of the spleen, and elsewhere: polymorphonuclear corpuscles and eosinophil cells are derived from the myelocytes of red marrow. Some observers believe, however, that all other forms of leucocytes are developed ultimately from lymphocytes. Leucocytes may also multiply by division, which, in some cases at least, is amitotic.

The **blood-platelets** (fig. 42) are discoid or irregularly shaped, colourless, refractile bodies, much smaller than the red corpuscles. Each contains a central chromatin mass resembling a nucleus. Blood-platelets possess the power of amoeboid movement. When blood is shed they rapidly disintegrate and form granular masses, setting free *thrombokinas*, a substance which takes part in the production of fibrin and so is concerned in bringing about the coagulation of the blood. It is doubtful whether platelets exist normally in circulating blood.

LYMPH

Lymph is a transparent, colourless or slightly yellow fluid, which is conveyed into the blood by a set of vessels named *lymphatics*. These vessels arise in nearly all parts of the body as *lymph-capillaries*. They take up the fluid which has exuded

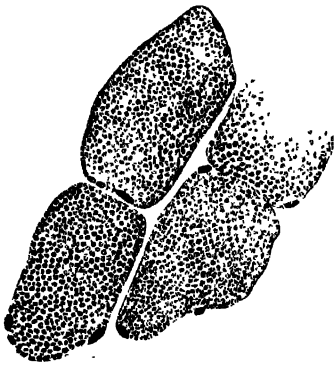
from the blood-capillaries for the nourishment of the tissue-elements, and return it into the veins. The greater number of these lymphatic vessels empty themselves into the *thoracic duct*, which ascends in front of the vertebral column and opens into the junction of the internal jugular and subclavian veins on the left side of the root of the neck. The remainder empty themselves into a smaller duct which ends in the corresponding veins on the right side of the neck.

Lymph is a watery fluid of sp. gr. about 1.015; it closely resembles the blood-plasma, but is more dilute. When it is examined under the microscope, leucocytes of the lymphocyte class are found floating in the transparent fluid; they are always increased in number after the passage of the lymph through lymphoid tissue, as in lymph-glands.

MUSCULAR TISSUE

Muscular tissue is composed of bundles of reddish fibres endowed with the property of contractility. There are three varieties of muscle, (1) *striped* or *voluntary*, (2) *unstriped* or *involuntary*, and (3) *cardiac*. The muscles which are concerned

FIG. 43.—Transverse section of human striped muscle-fibres.
× 255.



with the movements of the bony skeleton, the skeletal muscles, are composed of striped fibres, and are under the control of the will. The muscular coats of the stomach and intestines, uterus, bladder and blood-vessels, on the other hand, are formed of unstriped fibres, and their movements are involuntary. Some striped muscles, however, are not under voluntary control, namely, those forming the walls of the pharynx and upper part of the œsophagus; the ciliary muscle of the eye, though composed of unstriped fibres, is a voluntary muscle. Cardiac muscle is intermediate in position between the other two varieties. Its fibres are striped, but involuntary, and they differ from both striped and unstriped muscle in structure.

Striped fibres are arranged in bundles or *fasciculi*, in which the individual fibres are parallel to each other. Each fasciculus has a connective tissue sheath, called the *perimysium*, prolongations of which run into the bundle, binding the fibres together and constituting the *endomysium*. A muscle is composed of a number of fasciculi, held together and surrounded by connective tissue which is known as the *epimysium*. The fasciculi are of different sizes in different muscles, and are for the most part placed parallel to each other, though they usually converge towards the tendinous attachments. The connective tissue framework of the muscle contains the blood-vessels and nerves which supply it.

A *muscular fibre* may be said to consist of a soft contractile substance, enclosed in a tubular sheath named by Bowman the *sarcolemma*. The fibres are cylindrical or prismatic in shape (fig. 43), and are of no great length, not exceeding as a rule 40 mm. Their breadth varies in man from 0.01 mm. to 0.1 mm. As a rule, the fibres do not divide or anastomose; but occasionally, especially in the tongue and facial muscles, they may be seen to divide into several branches. In the substance of the muscle, the fibres end by tapering extremities which are joined to the ends of other fibres by the sarcolemma. Where a muscle joins its tendon, the sarcolemma covering the end of each muscle-fibre blends with a corresponding group of the fine fibres of the tendon. The muscular substance of the fibre can readily be made to retract from the point of junction. The areolar tissue between the fibres is prolonged more or less into the tendon, so as to form a kind of sheath around the tendon-bundles for a longer or shorter distance. When muscular fibres are attached to skin or mucous membranes, this sheath becomes continuous with the areolar tissue of these structures.

The *sarcolemma*, or tubular sheath of the fibre, is a transparent, elastic, and apparently homogeneous membrane of considerable toughness, so that it sometimes

remains entire when the included substance is ruptured. On the internal surface of the sarcolemma in mammalia, and also in the substance of the fibre in frogs, elongated nuclei are seen, and in connexion with these is a little granular protoplasm.

Upon examination of a voluntary muscular fibre by transmitted light, it is found to be marked by alternate light and dark bands or striæ, which pass transversely across the fibre (fig. 44). When examined by polarised light the dark bands are found to be doubly refracting (anisotropic), while the clear stripes are singly refracting (isotropic). The dark and light bands are of nearly equal breadth, and alternate with great regularity; they vary in breadth from about 1μ to 2μ . When the fibre is deeply focussed a dark line may be seen running in the middle of the clear stripe. This is known as *Dobie's line* or *Krause's membrane*. In fibres which are in the extended condition the dim stripe is often seen to be divided by a clearer line, *Hensen's line*.

Under high magnification there are indications that the striped muscle-fibre is made up of a large number of fibrils, known as *sarcostyles* or muscle-columns, together with an interfibrillar material, or *sarcoplasm* (fig. 45, B). When a fibre is treated with weak acid it becomes clearer, and the sarcoplasm is visible as fine, longitudinal, parallel lines. At the junction of the dim and clear stripes these lines often show bead-like enlargements in the extended condition of the fibre. In transverse sections the sarcostyles appear as minute, polygonal areas, each surrounded by clear sarcoplasm, which then appears to form a network. The small areas are known as *Cohnheim's areas*.

When the sarcostyles are separated by suitable methods it becomes evident that each exhibits alternate dim and clear portions, with *Dobie's* and *Hensen's* lines, and that the striped appearance of the fibre is due to the apposition of the corresponding segments of the fibrils of which it is composed.

Schäfer has worked out the minute anatomy of muscular fibre, particularly in the wing muscles of insects, which are peculiarly adapted for this purpose on account of the relatively large size of the sarcostyles and

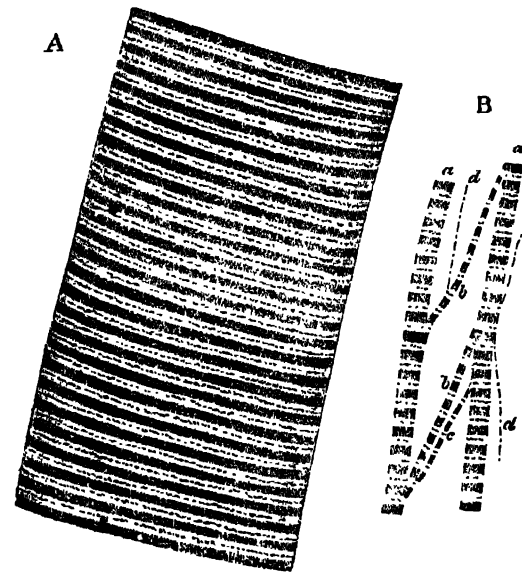
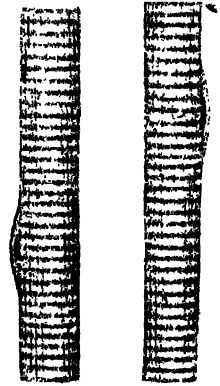


FIG. 45.—A. Portion of a medium-sized human muscular fibre. Magnified nearly 800 diameters. B. Separated bundles of fibrils, equally magnified.

the ease with which they can be separated given by Schäfer is closely followed.

A sarcostyle may be said to be made up of successive portions, each of which is termed a *sarcomere*. The sarcomere is situated between two membranes of *Krause*, and consists of (1) a central dark part, which forms a portion of the dark band of the whole fibre, and (2) a clear area at either end, each forming, with the corresponding clear part of the adjacent sarcomere, the light band of the fibril. The central dark segment really consists of two parts, and when the fibre is stretched these two parts become separated from each other at the line of *Hensen* (fig. 46, A).

FIG. 44.—Striped muscle-fibres from the tongue of a cat. $\times 250$.



The clear areas are well marked in the extended sarcostyle, but in the contracted sarcostyle they are small or altogether absent (fig. 46, B).

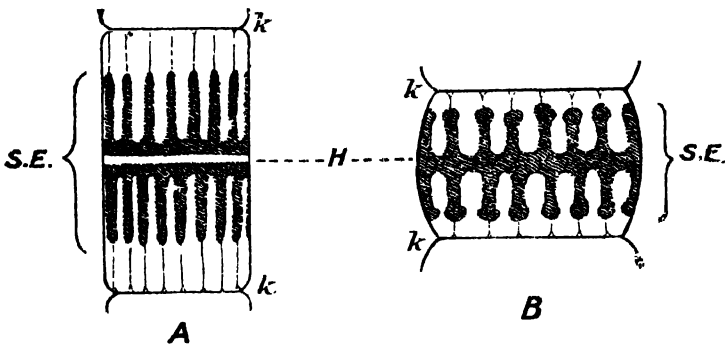
The central dim portion, or *sarcous element*, does not lie free in the sarcomere, for when the sarcostyle is stretched, so as to render the clear portion visible, very fine lines, which are probably septa, may be seen running through it from the sarcous element to the membrane of Krause.

Schäfer explains these phenomena in the following way. He considers that each dim segment contains a number of longitudinal channels, which open into the clear part towards the membrane of Krause but are closed at the line of Hensen. When the muscular fibre contracts the clear part of the muscular substance passes into these channels or tubes, and is therefore hidden from sight, but at the same time it swells up the sarcous element and widens and shortens the sarcomere. When, on the contrary, the fibre is extended, this clear substance is driven out of the tubes and collects between the sarcous element and the membrane of Krause, and gives the appearance of the light part between these two structures; by this means it elongates and narrows the sarcomere.

Schäfer has shown that, if this view be correct, it harmonises the contraction of muscle with the amoeboid action of protoplasm. In an amoeboid cell there is, according to one view of the structure of protoplasm, a framework of spongioplasm,

FIG. 46.—Diagram of a sarcomere. (After Schäfer.)

A. In a moderately extended condition. B. In a contracted condition.



H. Line of Hense k, k Membranes of Krause. S.E. Sarcous element.

enclosing in its meshes a clear substance, hyaloplasm. Under stimulation the hyaloplasm passes into the pores of the spongioplasm; without stimulation it tends to pass out, as in the formation of pseudopodia. In muscle there is the same thing, viz. a framework of spongioplasm the substance of the dim segment: and this encloses a clear hyaloplasm, the clear substance of the sarcomere. During contraction of the muscle—i.e. under stimulation—this clear substance passes into the pores of the spongioplasm; while during extension of the muscle—i.e. when there is no stimulation—it tends to pass out of the spongioplasm. In this way the contraction is brought about: under stimulation the protoplasmic material (the clear substance of the sarcomere) recedes into the sarcous element, causing the sarcomere to widen out and shorten. The contraction of the muscle is merely the sum total of this widening out and shortening of these bodies.

Vessels and nerves of striped muscle.—The *capillaries* of striped muscle are very abundant, and form a sort of rectangular network, the branches of which run longitudinally in the endomysium between the muscular fibres, and are joined at short intervals by transverse anastomosing branches. In the red muscles of the rabbit dilatations occur on the transverse branches of the capillary network. The larger vascular channels, arteries and veins, are found only in the perimysium, between the muscular fasciculi. *Nerves* are profusely distributed to striped muscle. Their mode of termination is described in the chapter on Neurology. *Lymphatic vessels* do not occur in striped muscle, though they have been found in tendons and in the sheaths of the muscles.

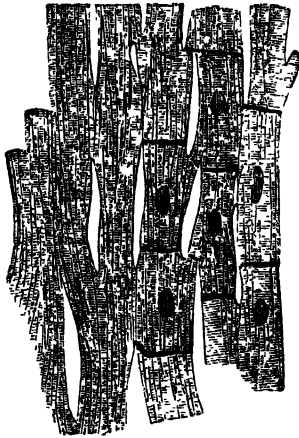
Unstriped, plain, or involuntary muscle is found in the following situations—in the lower half of the œsophagus and the whole of the remainder of the gastro-

intestinal tube; in the trachea and bronchi; in the gall-bladder and common bile-duct; in the large ducts of the salivary and pancreatic glands; in the pelvis and calyces of the kidney, the ureter, bladder, and urethra; in the female sexual organs—viz. the ovary, the uterine tubes, the uterus (enormously developed in pregnancy), the vagina, the broad ligaments, and the corpora cavernosa of the clitoris; in the male sexual organs—viz. the Dartos of the scrotum, the ductus deferentes and epididymes, the vesiculæ seminales, the prostate, and the corpora cavernosa of the penis and urethra; in the capsule and trabeculæ of the spleen; in the mucous membranes, forming the muscularis mucosæ; in the skin, forming the Arrectores pilorum, and also in the sweat-glands; in the arteries, veins, and lymphatics; in the iris and the ciliary muscle.

Unstriated or plain muscle is made up of spindle-shaped cells (fig. 47), collected into bundles and held together by a cement-substance. These bundles are further aggregated into larger fasciculi, or sheets, bound together by ordinary connective tissue.

The cells are elongated, spindle-shaped, and nucleated, and are of various sizes, averaging from 40μ to 80μ in length, and 6μ to 7μ in breadth. On transverse section they are more or less polyhedral in shape, from mutual pressure.

FIG. 48.—Anastomosing muscular fibres of the heart seen in a longitudinal section. On the right the limits of the separate cells with their nuclei are exhibited somewhat diagrammatically.

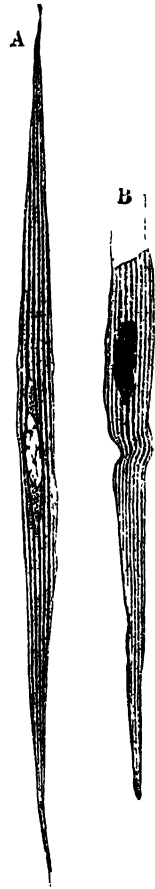


Each presents a faint longitudinal striation and consists of an elastic cell-wall containing the contractile substance, and an oval or rod-like nucleus. A centriole lies close to the nucleus.* The fibres are attached to one another by a certain amount of interstitial cement-substance which reduces nitrate of silver, but in some regions, e.g. the muscular coats of the intestines, the muscle-cells are also connected by 'bridges' similar to those which occur in the prickles of the epidermis.

Sheets of smooth muscle frequently exhibit rhythmical contractions, which are more sluggish than the contractions of striped muscle and in many cases travel along the membrane in the form of waves. Such waves are well marked in the wall of the intestine. Contraction is often excited by a mechanical stimulus, as distension, for example, in the urinary bladder.

Cardiac muscular tissue.—The fibres of the heart differ very remarkably from those of other striped muscles. They are striated both transversely and longitudinally, but the striation, as compared with that of striped muscle, is faint and indistinct. The fibres are made up of quadrangular cells joined end to end so as

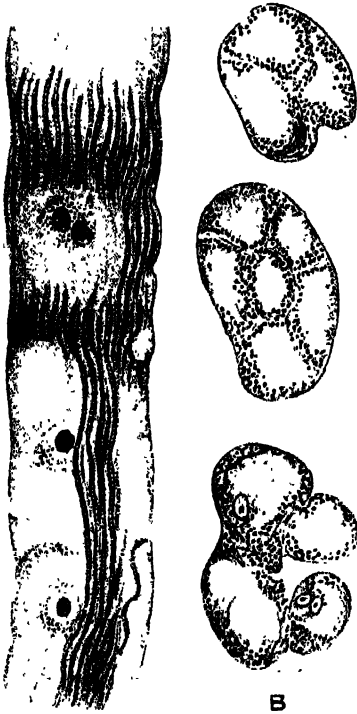
FIG. 47.—Muscle-fibres from the small intestine. From Quain's Elements of Anatomy, vol. ii. pt. i. Microscopic Anatomy.



A.—Complete cell. B. Broken cell showing delicate external layer.

to form a syncytium (fig. 48). Each cell contains a clear oval nucleus, situated near its centre. Many of the cells branch or divide, the subdivisions uniting with offsets from other cells, and thus producing an anastomosis of the fibres. The connective tissue between the bundles of fibres is much less than in ordinary striped muscle, and no sarcolemma has been proved to exist.

FIG. 49.—Purkinje's fibres from the sheep's heart.



A. In longitudinal section
B. In transverse section.

Purkinje's fibres (fig. 49).—Between the endocardium and the ordinary cardiac muscle are found, embedded in a small amount of connective tissue, peculiar fibres known as *Purkinje's fibres*. They are associated with the terminal distributions of the atrioventricular bundle. The fibres are very much larger in size than the cardiac cells and differ from them in several ways. In longitudinal section they are quadrilateral in shape, being about twice as long as they are broad. The central portion of each fibre contains one or more nuclei and is made up of granular protoplasm, with no indication of striation, while the peripheral portion is clear and has distinct transverse striations. The fibres are intimately connected with each other, possess no definite sarcolemma, and do not branch. They form a considerable portion of the moderator band in the heart of the sheep.

The **atrioventricular bundle** (see chapter on Angiology) is composed of cells which differ from ordinary cardiac muscle-cells in being more spindle-shaped. They are, moreover, more loosely arranged and have a richer vascular supply than the rest of the heart-muscle.

Development of muscle-fibres. Voluntary muscular fibres are developed from the mesoderm, the embryonic cells of which elongate, show multiplication of nuclei, and eventually become striated; the striation is first obvious at the side of the fibres, spreads around the circumference, and ultimately extends to the

centre. The nuclei, at first situated centrally, gradually pass out to assume their final position immediately beneath the sarcolemma. In the case of involuntary muscle the mesodermal cell assumes a pointed shape at the extremities and becomes flattened, the nucleus also lengthening out to its permanent rod-like form.

NERVOUS TISSUE

The **nervous tissues** of the body comprise the brain, the medulla spinalis or spinal cord, the cerebral, spinal, and sympathetic nerves, and the ganglia connected with them.

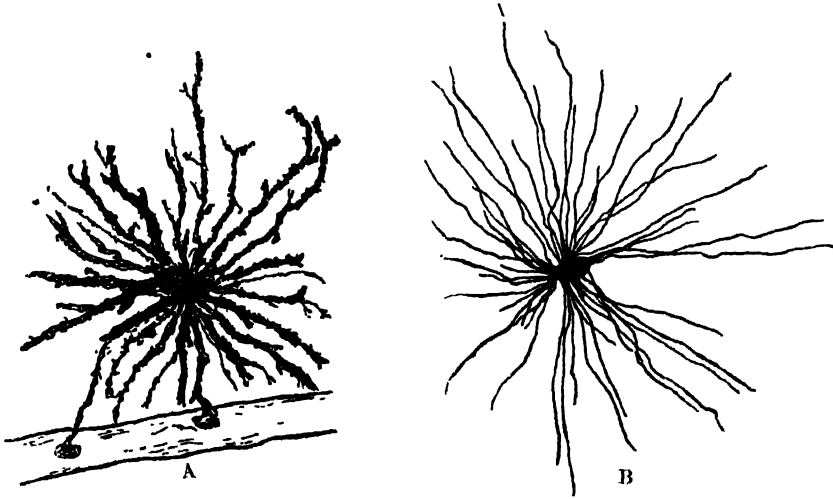
The nervous tissues are composed of *nerve-cells* and their various processes, together with a supporting tissue called *neuroglia*, which, however, is found only in the brain and medulla spinalis. Certain long processes of the nerve-cells are of special importance, and it is convenient to consider them apart from the cells; they are known as *nerve-fibres*.

To the naked eye a difference is obvious between certain portions of the brain and medulla spinalis, viz. the *grey substance*, and the *white substance*. The grey substance is largely composed of nerve-cells, while the white substance contains only their long processes, the nerve-fibres. It is in the former that nervous impressions are received, stored, and transformed into efferent impulses, and by the latter that they are conducted. Hence the grey substance forms the essential constituent of all the ganglionic centres, both those in the isolated ganglia and

those aggregated in the brain and medulla spinalis; while the white substance forms the bulk of the commissural portions of the nerve-centres and the peripheral nerves.

Neuroglia, the peculiar variety of connective tissue which binds together the true nervous constituents of the brain and medulla spinalis, consists of cells and fibres. Some of the cells (spider-cells) are stellate in shape, with ill-defined cell-body, and their fine processes become neuroglia fibres, which extend radially and unbranched (fig. 50, B) among the nerve-cells and fibres which they aid in supporting.

FIG. 50.—Neuroglia cells of the brain shown by Golgi's method. (After Andriezen.)
(From Schäfer's Essentials of Histology.)



A. Arborescent cell with branched processes.

B. Spider-cell with unbranched processes.

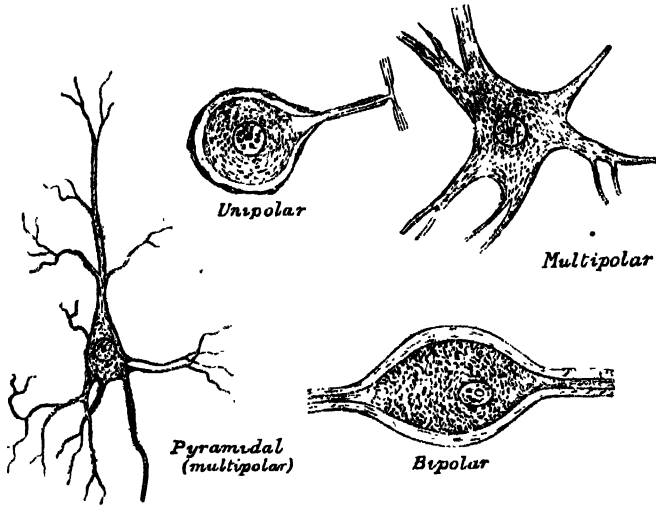
Other cells (arborescent cells) give off processes which branch repeatedly (fig. 50, A). Some of the fibres start from the epithelial cells lining the ventricles of the brain and central canal of the medulla spinalis, and pass through the nervous tissue, branching repeatedly, to end in slight enlargements on the pia mater. Thus, neuroglia is evidently a connective tissue in function, but it is not so in development; it is ectodermal in origin, whereas all other connective tissues are mesodermal.

Nerve-cells (fig. 51) are largely aggregated in the grey substance of the brain and medulla spinalis, but smaller collections of these cells also form the swellings, called *ganglia*, seen on many nerves. These latter are found chiefly upon the spinal and cerebral nerve-roots and in connexion with the sympathetic nerves.

Nerve-cells vary in shape and size, and have one or more processes. They may be divided for purposes of description into three groups according to the number of processes which they possess: (1) Unipolar cells are found in the spinal ganglia; the single process, after a short course, divides in a T-shaped manner (fig. 51). These cells are bipolar in embryonic life, but, as development proceeds, the two processes approach one another and become fused for a short distance. In the spinal ganglia of fish the cells are bipolar throughout life. (2) Bipolar cells (fig. 51) are found, in the adult, in the retina, and in the ganglion spirale and ganglion vestibulare of the acoustic nerve. In some cases where two fibres are apparently connected with a cell, one of the fibres is really derived from an adjoining nerve-cell and is passing to end in a ramification around a unipolar cell, or, again, it may be coiled spirally round the nerve-process which is issuing from the cell. (3) Multipolar cells are pyramidal or stellate in shape, and characterised by the numerous processes which issue from them. The processes are of two kinds: one of them is termed the *axis-cylinder process* or *axon* because it becomes the axis-

cylinder of a nerve-fibre (figs. 52, 53, 54). The others are termed the *protoplasmic processes* or *dendrons*; they begin to divide and subdivide as soon as they emerge from the cell, and finally end in minute twigs. The axons of certain multipolar

FIG. 51.—Various forms of nerve-cells.



cells found in the brain and medulla spinalis do not become nerve-fibres, but terminate by arborescence close to the cell-body. Such cells were called by Golgi multipolar cells of the second type.

The body of the nerve-cell is known as the *cyton*. In fixed and stained preparations it consists of a finely fibrillated protoplasmic material, of a reddish or yellowish-brown colour, which occasionally presents patches of a deeper tint, caused by the

FIG. 52.—Motor nerve-cell from the ventral horn of medulla spinalis of an ox. $\times 500$. The spindle-shaped Nissl's granules are shown. The dendrons and axon are broken off close to the cell.

Dendrons

Axon

aggregation of pigment-granules at one side of the nucleus, as in the substantia nigra and locus cæruleus of the brain. The protoplasm also contains peculiar angular granules, which stain deeply with basic dyes such as methylene blue; these are known as *Nissl's granules* (fig. 52). They extend into the dendritic processes but not into the axis-cylinder; the small clear area at the point of exit of the axon is termed the *cone of origin*. These granules disappear (*chromatolysis*) during fatigue or after section of the nerve-fibres connected with the cells. They are supposed to

represent a store of nervous energy, and in various mental diseases are deficient or absent. The nucleus is, as a rule, a large, well-defined body, with a relatively small amount of chromatin, and containing a well-marked nucleolus.

FIG. 53.—Pyramidal cell from the cerebral cortex of a mouse. Golgi method. (After Ramón y Cajal.)

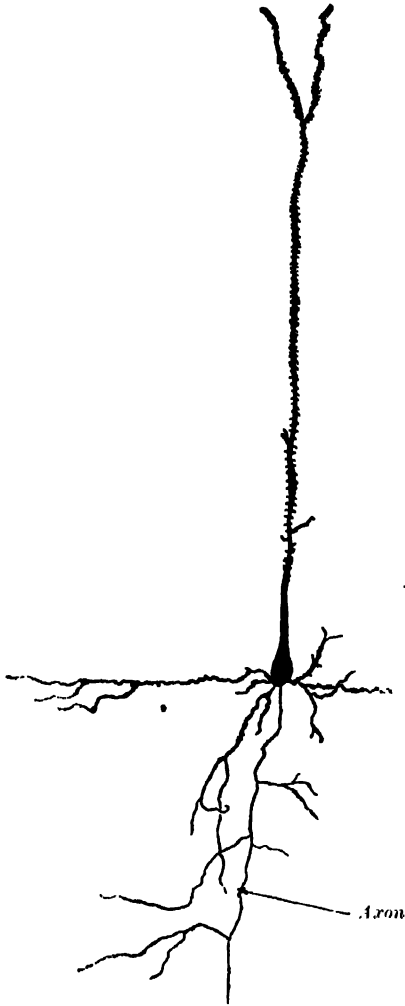
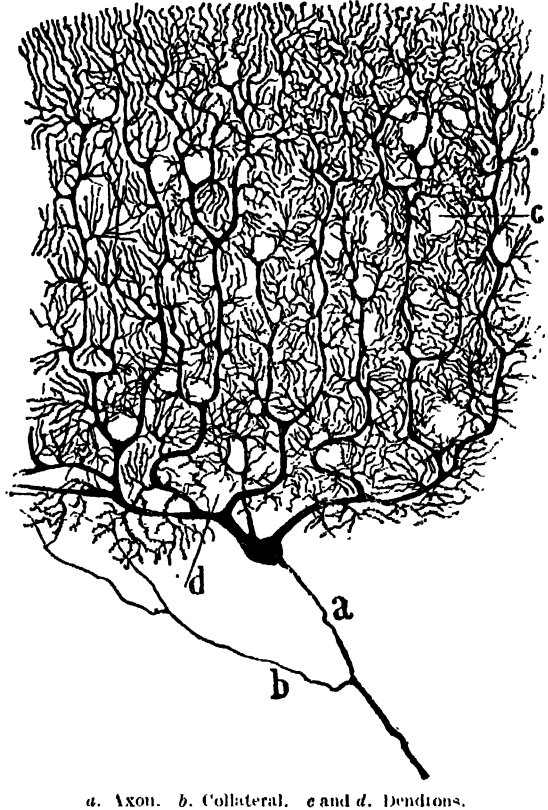


FIG. 54.—Cell of Purkinje from the cerebellum. Golgi method. (Ramón y Cajal.)



a. Axon. b. Collateral. c and d. Dendrons.

In addition to the protoplasmic network described above, each nerve-cell may be shown to have delicate neurofibrils running through its substance (fig. 55); these fibrils are continuous with the fibrils of the axon, and are believed to convey nerve-impulses. Golgi has also described an extracellular network, which is probably a supporting structure.

Mott and Marinesco have shown that, when living nerve-cells are examined by the dark ground illumination method, neither Nissl's granules nor fibrils of any kind can be seen. The constancy of the occurrence of both these structures in fixed preparations, however, indicates that they represent something specific in the living cell.

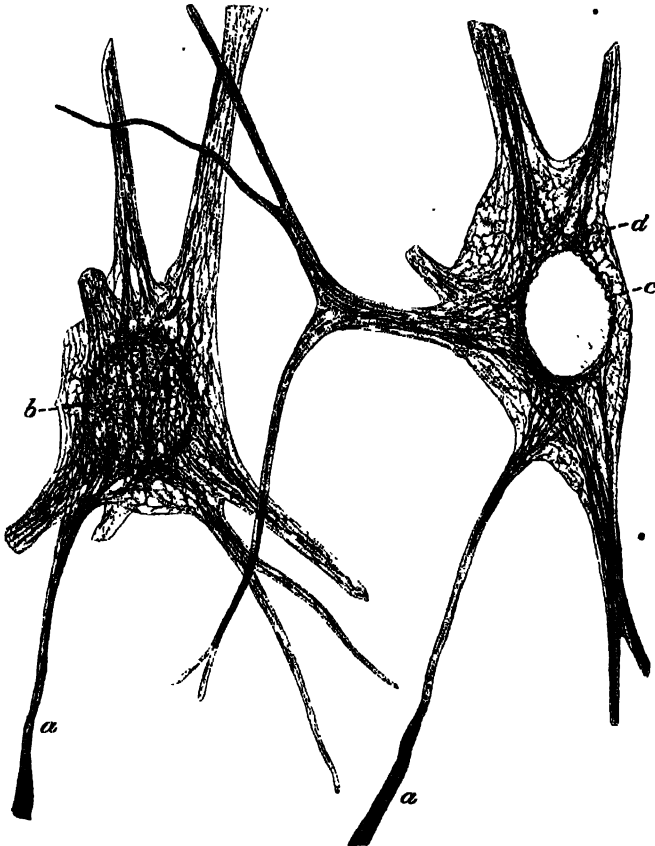
Nerve-fibres are found universally in the peripheral nerves, and in the white substance of the brain and medulla spinalis. They are of two kinds—viz. *medullated* or *white* fibres, and *non-medullated* or *grey* fibres.

The *medullated fibres* form the white part of the brain and medulla spinalis, and also the greater part of every cerebral and spinal nerve, and give to these structures their opaque, white aspect. When perfectly fresh they appear to be homogeneous;

but soon after removal from the body each fibre presents, when examined by transmitted light, a double outline or contour, as if consisting of two parts (fig. 56). The central portion is named the *axis-cylinder*; around this is a sheath of fatty material, staining black with osmic acid, named the *white substance of Schwann* or *medullary sheath*, which gives to the fibre its double contour; and the whole is enclosed in a delicate membrane, the *neurolemma*, *primitive sheath*, or *nucleated sheath of Schwann* (fig. 57). Medullated nerve-fibres vary in diameter from 2μ to 16μ .

The *axis-cylinder* is the essential part of the nerve-fibre, and is always present; the medullary sheath and the neurolemma are occasionally absent, especially at the origin and termination of the nerve-fibre. The axis-cylinder undergoes no interruption from its origin in the nerve-centre to its termination, and must be

FIG. 55.—Nerve-cells of a kitten, showing neurofibrils. (Ramón y Cajal.)



a. Axon. b. Cyton. c. Nucleus. d. Neurofibrils.

regarded as a direct prolongation of a nerve-cell. Nerve-fibres in the white substance of the brain and medulla spinalis differ from those in the peripheral nerves in that they give off twigs known as *collaterals*. These arise from the main fibre at right angles to its course and run into the grey substance, where they terminate by arborisation. The axis-cylinder constitutes about one-half or one-third of the nerve-fibre, being greater in proportion in the fibres of the central organs than in those of the nerves. It is quite transparent, and is therefore indistinguishable in a perfectly fresh and natural state of the nerve. It is made up of exceedingly fine fibrils (figs. 57 and 58), which stain darkly with gold chloride, and at its termination may be seen to break up into these fibrils. The axis-cylinder is said by some to be enveloped in a special reticular sheath, which separates it from the medullary sheath, and is composed of a substance called *neurokeratin*. The more common opinion is that this network or reticulum is contained in the white substance of Schwann, and by some it is believed to be produced by the action of the reagents employed to show it.

The *medullary sheath* or *white substance of Schwann* (fig. 57) is regarded as being a fatty material in a fluid state, which insulates and protects, or possibly supplies nutriment to, the essential part of the nerve - the axis-cylinder. As a general rule its thickness is proportional to the size of the axis-cylinder, and is such that it forms about half of the total area of the cross section of the fibre. Its continuity is interrupted at regular intervals, giving to the fibre the appearance of constriction at these points; these are known as the *nodes of Ranvier* (figs. 56 and 57). The portion of nerve-fibre between two nodes is called an *internodal segment*. The neurolemma or primitive sheath is not interrupted at the nodes, but passes over them as a continuous membrane. Some observers, however, believe that the neurolemma of one internodal segment is connected with that of the adjacent segment at the node by cement-substance. If the fibre be treated with silver nitrate the reagent penetrates the neurolemma at the nodes, and, on exposure to light, reduction takes place, giving rise to the appearance of black crosses, *Ranvier's crosses*, on the axis-cylinder. There may also be seen transverse lines beyond the nodes termed *Frommann's lines* (fig. 59); the significance of these is not understood. In addition to these interruptions oblique clefts or *incisures* may be seen in the

g. 56.—Medullated nerve-fibres. $\times 350$.

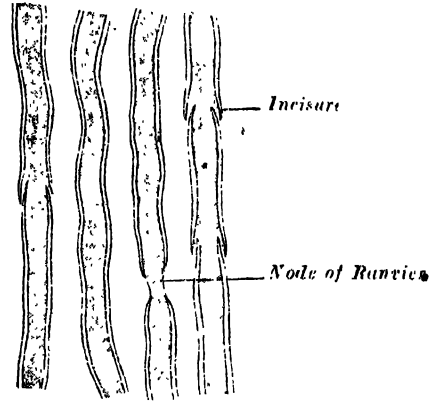
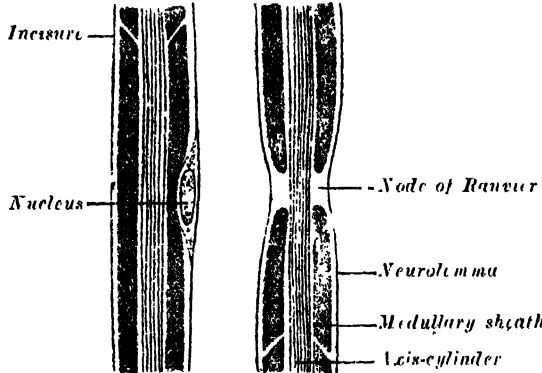
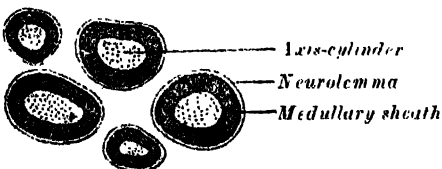


FIG. 57.—Diagram of longitudinal sections of medullated nerve-fibres. Osmic acid.



medullary sheath, subdividing it into irregular portions, which are termed *medullary segments*, or *segments of Lantermann* (fig. 57); there is reason to believe that these clefts are artificially produced in the preparation of the specimens. Medullated nerve-fibres, when examined in the fresh condition, frequently present a beaded or varicose appearance, due to manipulation and pressure causing the oily matter to collect into drops; in consequence of the extreme delicacy of the primitive sheath even slight pressure will cause the transudation of the fatty matter, which collects as drops of oil outside the sheath.

FIG. 58.—Transverse sections of medullated nerve-fibres. Osmic acid.



in depressions in the white substance of Schwann, are nuclei surrounded by a small amount of protoplasm. The nuclei are oval and somewhat flattened, and one is

generally found in the middle of each internode. The primitive sheath is absent from the medullated fibres of the brain and medulla spinalis.

Wallerian Degeneration.—When nerve-fibres are cut across, the central ends of the fibres degenerate as far as the first node of Ranvier; but the peripheral ends degenerate simultaneously throughout their whole length. The axons break up into fragments and become surrounded by drops of fatty substance which are formed from the breaking down of the medullary sheath. The nuclei of the primitive sheath proliferate, and finally

FIG. 59.—Medullated nerve-fibres stained with silver nitrate.

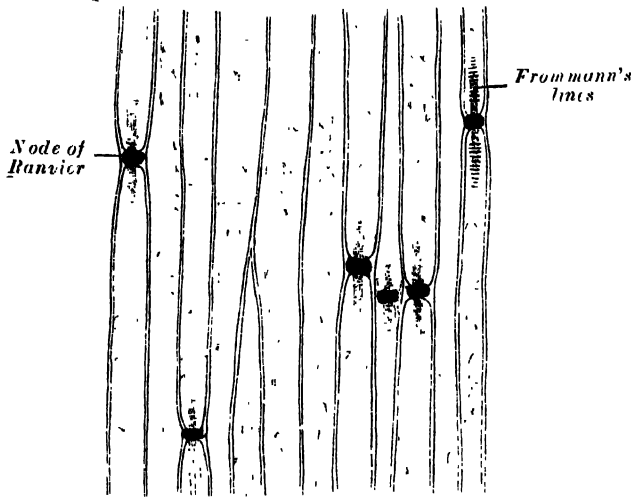


FIG. 60.—A small branch from the sympathetic of a mammal.



a. Two small medullated nerve-fibres among a number of non-medullated nerve-fibres. b.

absorption of the axons and fatty substance occurs. If the cut ends of the nerve be sutured together regeneration of the nerve-fibres takes place by the downgrowth of axons from the central end of the nerve. At one time it was believed that the regeneration was peripheral in origin, but this has been disproved, the proliferated nuclei in the peripheral portions taking part merely in the formation of the so-called scaffolding along which the new axons pass.

Non-medullated fibres.—Most of the fibres of the sympathetic system, and some of the cerebrospinal, consist of the grey or gelatinous nerve-fibres—*fibres of Remak* (fig. 60). Each of these consists of an axis-cylinder to which nuclei are applied at intervals. These nuclei are believed to be in connexion with a delicate sheath corresponding with the neurolemma of the medullated nerve-fibre. In external appearance the non-medullated nerve-fibres are semitransparent and grey or yellowish-grey. The individual fibres vary in size, generally averaging about half the size of the medullated fibres.

EMBRYOLOGY

THE term **Embryology**, in its widest sense, comprises the various changes which take place during the growth of an animal from the egg to the adult condition; it is, however, usually restricted to the phenomena which occur before birth.

In vertebrate animals the development of a new being can only take place when a female germ-cell or *ovum* has been fertilised by a male germ-cell or *spermatozoon*. The ovum is a nucleated cell, and the complicated changes by which the various tissues and organs of the body are formed from it, after it has been fertilised, are the result of two general processes, viz. *segmentation* and *differentiation* of cells. Thus, the fertilised ovum undergoes repeated segmentation into a number of cells which at first closely resemble one another, but are, sooner or later, differentiated into two groups: (1) *somatic cells*, the function of which is to build up the various tissues of the body; and (2) *germinal cells*, which are destined for the perpetuation of the species.

Having regard to the main purpose of this work, it is impossible, in the space available in this chapter, to describe or illustrate fully, all the changes which occur during the development of the human body. Only the principal facts are given, and the student is referred for further details to one or other of the text-books * on human embryology.

THE OVUM

The ova are developed from the primitive germ-cells which are situated in the substance of the ovaries; each primitive germ-cell gives rise, by repeated divisions, to a number of smaller cells termed *oogonia* from which the *ova* or *primary oöcytes* are developed.

Human ova measure about 0.2 mm. in diameter, and are contained within the Graafian follicles of the ovaries †; as a rule each follicle contains a single ovum, but sometimes two or more are present. By the enlargement and subsequent rupture of a follicle at the surface of the ovary, an ovum is liberated and enters the uterine tube through which it is conveyed to the cavity of the uterus. Unless it be fertilised it is discharged from the uterus, but if fertilisation takes place it is retained there and is developed into a new being.

In appearance and structure the ovum (fig. 61) differs little from an ordinary cell, but distinctive names have been applied to its several parts; thus, the cell-substance is known as the *yolk* or *cytoplasm*, the nucleus as the *germinal vesicle*, and the nucleolus as the *germinal spot*. The ovum has a thick, transparent envelope named the *zona striata* or *zona pellucida*, and when the ovum is liberated from the Graafian follicle, several layers of cells, derived from those of the follicle, adhere to the outer surface of the *zona radiata*, and collectively constitute the *corona radiata*.

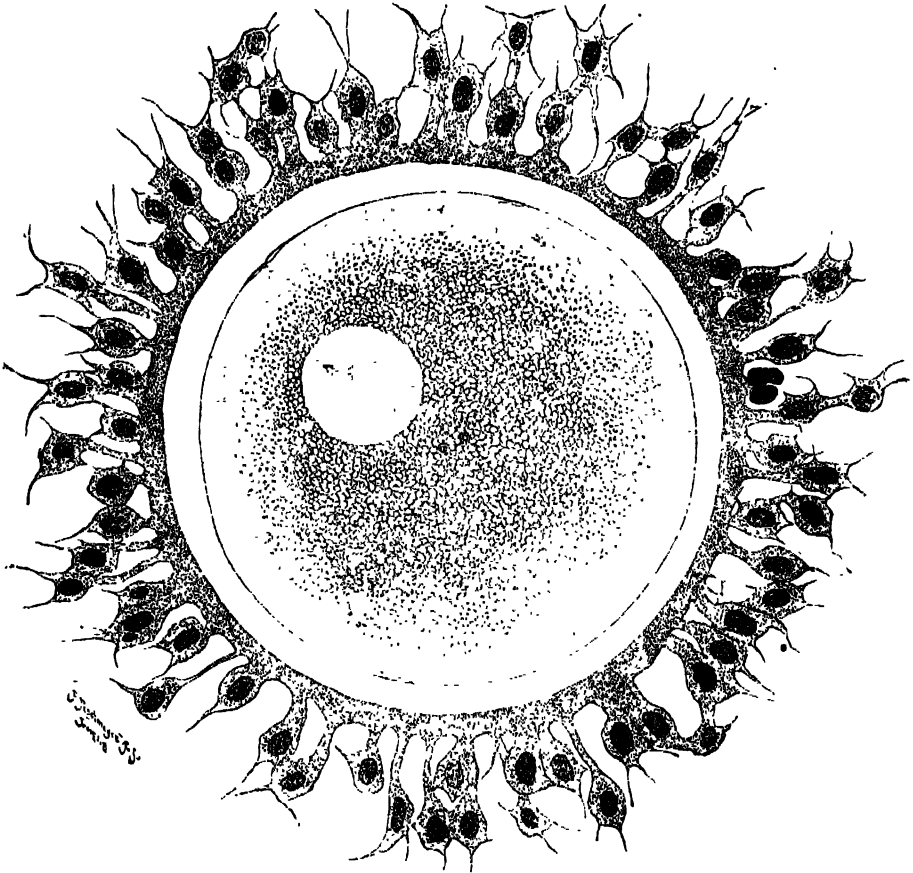
The **yolk** comprises (1) the *cytoplasm* of the ordinary animal cell with its spongioplasm and hyaloplasm; this is frequently termed the *formative yolk*; (2) the *deuterooplasm* or *nutritive yolk*, which consists of numerous rounded granules of fatty and albuminoid substances imbedded in the cytoplasm. • In the mammalian ovum the deuterooplasm is extremely small in amount, and is of service in nourishing the

* *Manual of Human Embryology*, Keibel and Mall; *Handbuch der vergleichenden und experimentellen Entwicklungslehre der Wirbeltiere*, Oskar Hertwig; *Lehrbuch der Entwicklungsgeschichte*, Bonnet; *Vertebrate Embryology*, Jenkinson; *The Physiology of Reproduction*, Marshall.

† See description of the ovary under Splanchnology.

embryo in the early stages of its development only, whereas in the egg of the bird there is sufficient to supply the chick with nutriment throughout the whole period of incubation. Its mode of distribution within the egg varies in different animals; in some it is almost uniformly dispersed throughout the cytoplasm; in some it is centrally placed and surrounded by the cytoplasm; in others it is accumulated at the lower pole of the ovum, while the cytoplasm occupies the upper pole. A *centrosome* and *centriole* are present and lie in the immediate neighbourhood of the nucleus.

FIG. 61.—Human ovum examined fresh in the liquor folliculi. $\times 500$. (Waldeyer.)



The zona pellucida is seen as a thick clear girdle surrounded by the cells of the corona radiata. The ovum shows a central granular deuterooplasmic area and a peripheral clear layer, and encloses the germinal vesicle, in which the germinal spot is seen.

The **nucleus** or **germinal vesicle** is a large spherical body which at first occupies a nearly central position, but becomes eccentric as the growth of the ovum proceeds. Its structure is that of an ordinary cell-nucleus, viz. it consists of a reticulum or karyomitome the meshes of which are filled with karyoplasm, while connected with, or imbedded in, the reticulum are a number of chromatin masses or chromosomes, which may present the appearance of a skein or may assume the form of rods or loops. The nucleus is enclosed by a delicate nuclear membrane, and contains in its interior a well-defined nucleolus or germinal spot.

COVERINGS OF THE OVUM

The **zona striata** or **zona pellucida** (fig. 61) is a thick membrane, which, under the higher powers of the microscope, is seen to be radially striated. It is not yet determined whether the zona striata is a product of the cytoplasm of the ovum or of the cells of the corona radiata, or of both.

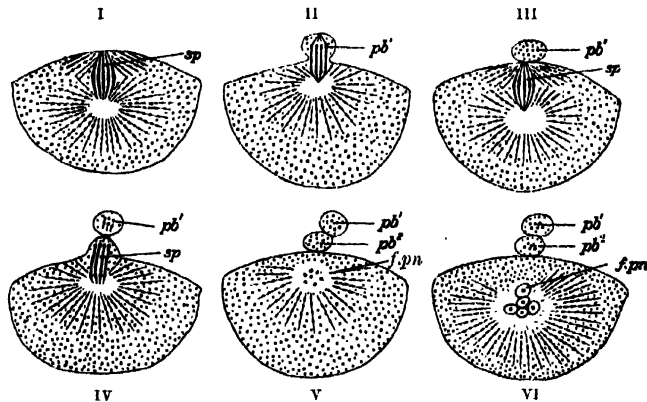
The *corona radiata* (fig. 61) consists of two or three strata of cells which are derived from the cells of the Graafian follicle, and adhere to the outer surface of the zona striata when the ovum is set free from the follicle; the cells are radially arranged around the zona, those of the innermost layer being columnar in shape. The cells of the corona radiata soon disappear; in some animals they secrete, or are replaced by, a layer of protein, which may assist in protecting and nourishing the ovum.

The phenomena attending the discharge of the ova from the Graafian follicles are described with the anatomy of the ovaries.

MATURATION OF THE OVUM

Before an ovum or primary oöcyte can be fertilised it must undergo a process of *maturation* or *ripening* (fig. 62). This process consists essentially of a heterotypical division of the ovum into two cells, followed by a homotypical division of the two cells into four; the heterotypical division occurs before the ovum is liberated

FIG. 62.—Formation of polar bodies in *Asterias glacialis*.
(Slightly modified from Hertwig.)



In fig. I the polar spindle (*sp*) has advanced to the surface of the egg. In fig. II a small elevation (*pb'*) is formed which receives half of the spindle. In fig. III the elevation is constricted off, forming the first polar body (*pb'*), and a second spindle is formed. In fig. IV is seen a second elevation which in fig. V has been constricted off as the second polar body (*pb''*). Out of the remainder of the spindle (*f.pn* in fig. VI) the female pronucleus is developed.

from the ovarian or Graafian follicle, the homotypical division usually after the spermatozoön has penetrated the zona striata. Three of the four cells are small, incapable of further development, and are named *polar bodies* or *polocytes*. The fourth cell is large; it is named the *mature ovum*, and is devoid of a centrosome. Its nucleus, as the result of the heterotypical division, contains only half the number of chromosomes which were present in the nucleus of the primary oöcyte. The nucleus of the mature ovum is named the *female pronucleus*.

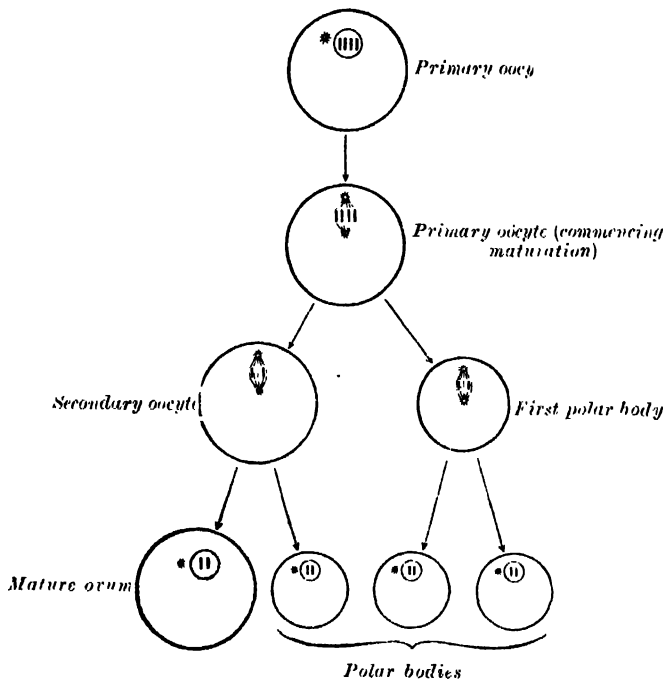
The process of maturation has not been observed in the human ovum, but has been carefully studied in the ova of some of the lower animals, to which the following description applies.

It was pointed out on page 2 that the number of chromosomes found in the nucleus is constant for all the cells in an animal of any given species, and that in man the number is probably twenty-four.* This applies not only to the somatic cells but to the primitive ova and their descendants. For the purpose of illustrating the process of maturation a species may be taken in which the number of nuclear chromosomes is four (fig. 63). If an ovum from such be observed at the beginning of the maturation process, the usual achromatic spindle is seen lying close to and parallel with the surface of the ovum, with the four chromosomes arranged at its

* H. von Winiwarter maintains that the number of chromosomes in the immature ovum is forty-eight, and in the primary spermatoöyte, forty-seven.

equator. The spindle then rotates so that its long axis is radial, and the first or heterotypical division takes place; two chromosomes pass to either end of the spindle, those at the periphery producing a surface elevation which is constricted off as the *first polar body*. The other two chromosomes are retained in the ovum, which is now termed a *secondary oöcyte*. Without passing through a resting stage the secondary oöcyte undergoes homotypical division, the two chromosomes each dividing into two, which travel to the ends of the spindle. A *second polar body* is

FIG. 63.—Diagram showing the reduction in number of the chromosomes in the process of maturation of the ovum.



segmented off, and the *mature ovum*, with two chromosomes gathered into a newly formed nucleus, remains. The first polar body frequently divides in a homotypical manner while the second is being formed, and as a final result four cells are produced, viz. the mature ovum and three polar bodies, each of which contains two chromosomes, i.e. half the number present in the nuclei of the somatic cells of members of the same species.

THE SPERMATOZOÖN

The spermatozoa or male germ-cells are developed in the testes and are present in enormous numbers in the seminal fluid; each consists of a small but greatly modified cell. The human spermatozoön possesses a head, a neck, a connecting piece or body, and a tail (fig. 64).

The **head** is ovoid or elliptical, but flattened, so that when viewed in profile it is pear-shaped. Its anterior two-thirds are covered by a layer of modified protoplasm, named the *head-cap*, which ends anteriorly in a sharp edge. In some animals (e.g. the salamander), the head-cap is prolonged into a barbed spear-like process (*acrosome* or *perforator*), which probably facilitates the entrance of the spermatozoön into the ovum.

The **neck** is less constricted in the human spermatozoön than in those of some of the lower animals. The *anterior centriole* is situated at the junction of the head and neck, and behind it is a band of homogeneous substance.

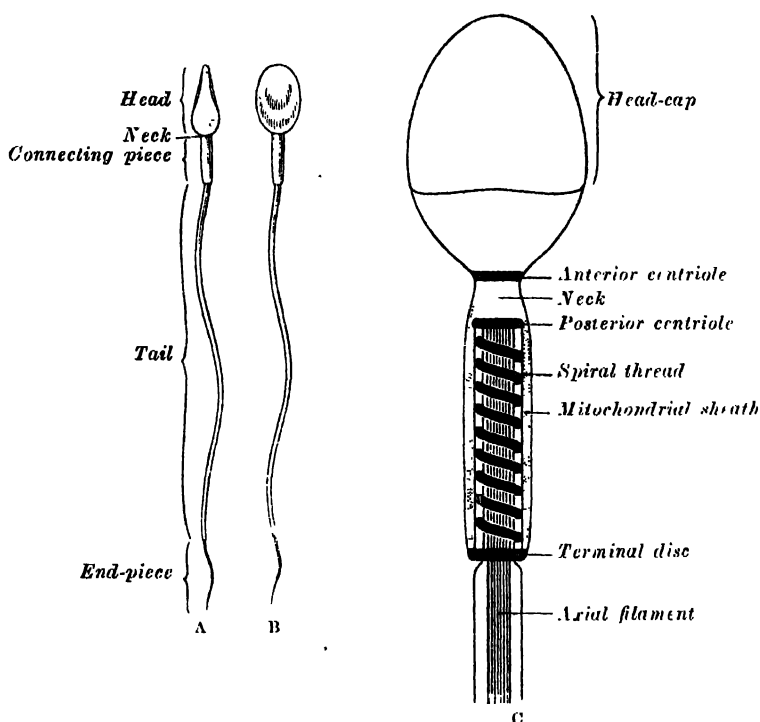
The **connecting piece** or **body** is rod-like, and is limited behind by a *terminal disc* or *ring*. The *posterior centriole* is placed at the junction of the body and neck,

and from it an *axial filament*, surrounded by a sheath, runs backwards through the body and tail. In the body the sheath of the axial filament is encircled by a *spiral thread*, around which is an envelope containing mitochondria granules, and termed the *mitochondrial sheath*.

The *tail* consists of the axial thread or filament, surrounded by a thin protoplasmic sheath; the terminal portion or *end-piece* of the tail is composed of the axial filament only.

Krause gives the length of the human spermatozoön as between 52μ and 62μ , the head measuring $4-5\mu$, the connecting piece 6μ , and the tail from 41μ to 52μ .

FIG. 64.—Human spermatozoa, highly magnified. A. Profile view. B. Surface view. (After Retzius.) C. Diagrammatic representation of the head, neck and connecting piece, more highly magnified. (Modified from Meeves.)



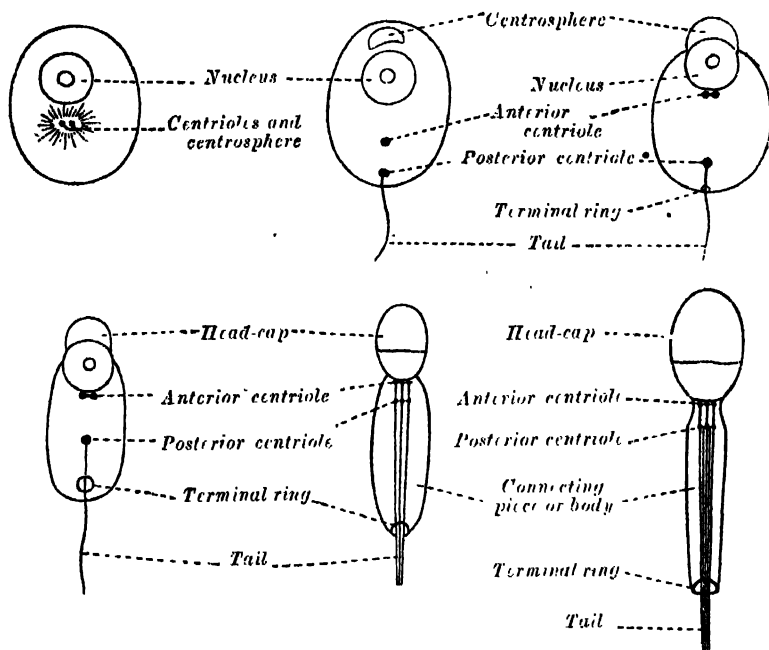
By virtue of their tails, which act as propellers, the spermatozoa are capable of free movement, and if placed in favourable surroundings (e.g. in the female passages) will retain their vitality and fertilising power for several days. In certain animals (e.g. bats) it has been proved that spermatozoa retained in the female passages for several months are capable of fertilising.

The spermatozoa are developed from the primitive germ-cells which have become imbedded in the testes, and the stages of their development are very similar to those of the maturation of the ovum. The primary germ-cells undergo division and produce a number of cells termed *spermatogonia*, and from these the *primary spermatocytes* are derived. Each primary spermatocyte undergoes a heterotypical division into two *secondary spermatocytes*, in the nuclei of which the number of chromosomes is reduced by half, and each secondary spermatocyte a homotypical division into two *spermatids* or young spermatozoa; from this it will be seen that each primary spermatocyte gives rise to *four* spermatozoa.

Interesting changes occur during the conversion of the spermatid into the spermatozoön (fig. 65). The two centrioles are at first placed tangentially to the surface of the spermatid but soon assume a radial position so that one lies deeper than the other; the deeper one forms the anterior centriole of the neck. The axial filament grows out from the superficial centriole which divides into two parts; the anterior part forms the posterior centriole of the neck, and the posterior part,

which is ring-like, migrates to the distal end of the connecting piece of body and there forms the terminal disc or ring, through which the axial filament passes. The nucleus of the spermatid forms the head of the spermatozoon, and the cytoplasm,

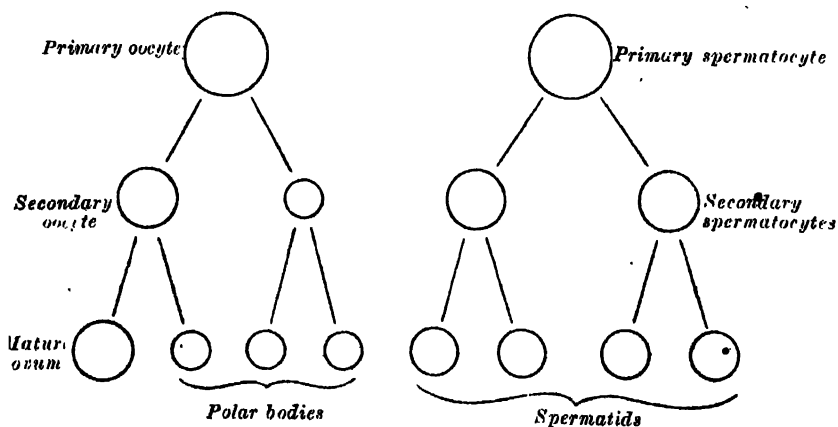
FIG. 65.—Transformation of spermatid into spermatozoon. (Diagrammatic.)
(Modified from Meeves.)



the investing sheath of the body and tail. The centrosphere moves away from the centrioles to the opposite side of the nucleus and is converted into the head-cap (acrosome).

On comparing the development of the spermatozoon with the maturation of the ovum (fig. 66) it will be observed that the primary spermatocyte gives rise to two

FIG. 66.—Scheme showing analogies in the process of maturation of the ovum and the development of the spermatids (young spermatozoa).



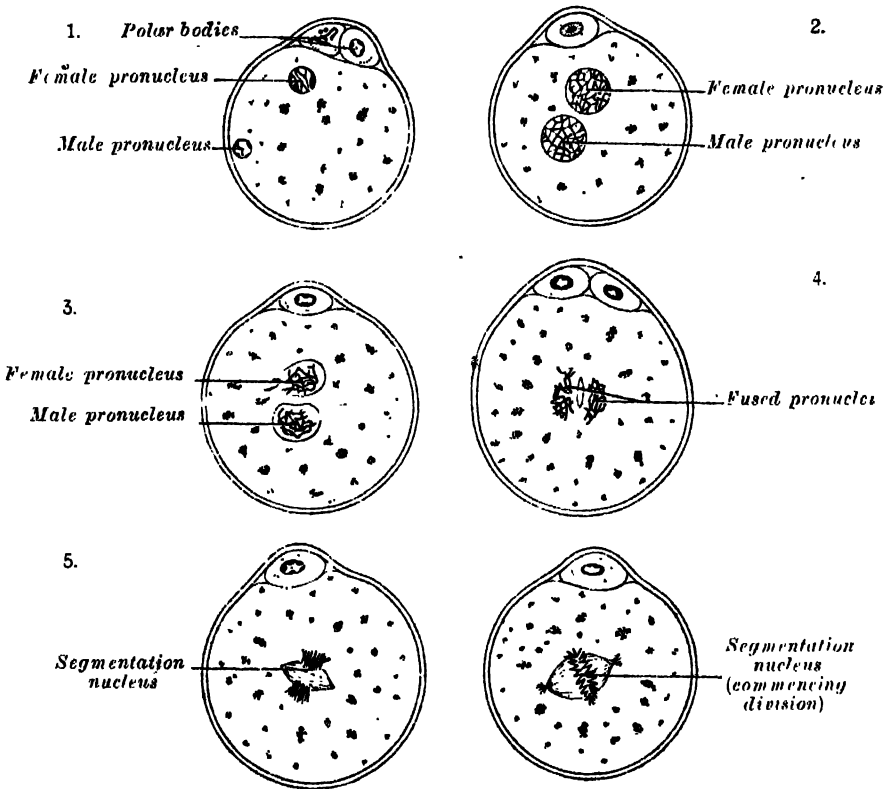
secondary spermatocytes, and the primary oocyte to the secondary oocyte and the first polar body; the two secondary spermatocytes give origin to four spermatozoa, and the secondary oocyte and first polar body to four cells, the mature ovum and three polar bodies. In the development of the spermatozoon, as in the maturation

of the ovum, there is a reduction of the nuclear chromosomes to one-half of those present in the primary spermatocyte. But here the similarity ends, for it must be noted that the four spermatozoa are of equal size, and each is capable of fertilising a mature ovum, whereas the three polar bodies are much smaller than the mature ovum, incapable of further development, and may be regarded as abortive ova.

FERTILISATION OF THE OVUM

Fertilisation consists in the union of the spermatozoön with the mature ovum (fig. 67). Nothing is known regarding the fertilisation of the human ovum, but the various stages of the process have been studied in other mammals, and from the knowledge so obtained it is believed that fertilisation of the human ovum takes place in the lateral or ampullary part of the uterine tube. The fertilised ovum is then conveyed along the tube to the cavity of the uterus—a journey probably

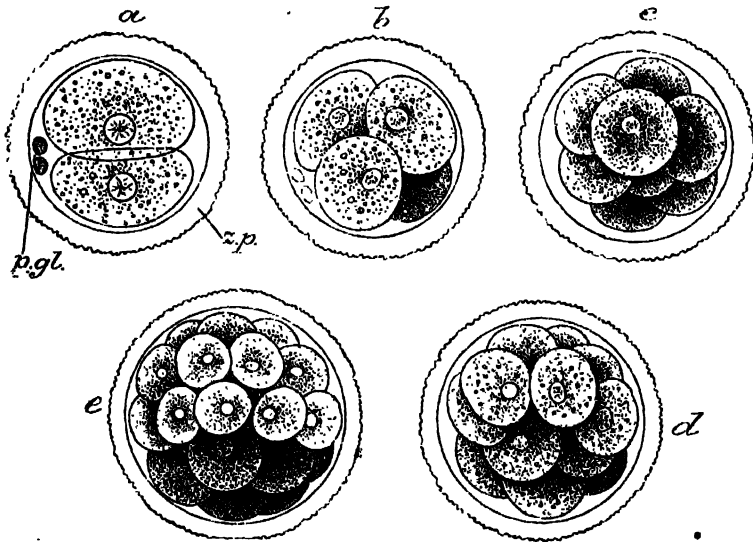
FIG. 67.—The process of fertilisation in the ovum of a mouse. (After Sobotta.)



occupying seven or eight days, and during which the ovum loses its corona radiata and zona striata and undergoes segmentation. Sometimes the fertilised ovum is arrested in the uterine tube, and there undergoes development, giving rise to a *tubal pregnancy*; or it may fall into the abdominal cavity and produce an *abdominal pregnancy*. Occasionally the ovum is not expelled from the Graafian follicle when the latter ruptures, but is fertilised within the follicle and produces what is known as an *ovarian pregnancy*. Under normal conditions only one spermatozoön enters the yolk and takes part in the process of fertilisation. At the point where the spermatozoön is about to enter, the yolk is drawn out into a conical elevation, termed the *cone of attraction*. As soon as the spermatozoön has penetrated the yolk, the peripheral portion of the latter is transformed into a membrane, the *vitelline membrane*, which prevents the entrance of additional spermatozoa. Occasionally a second spermatozoön may enter the yolk, thus giving rise to a condition of *poly-spermy*; when this occurs the ovum usually develops in an abnormal manner and

gives rise to a monstrosity. Having pierced the yolk, the spermatozoön loses its tail, while its head and connecting piece assume the form of a nucleus containing a cluster of chromosomes. This constitutes the *male pronucleus*, and associated with it there are a centrosome and centriole. The male pronucleus passes more deeply into the yolk, and the granules of the cytoplasm surrounding it become radially arranged. The male and female pronuclei migrate towards each other, and, meeting near the centre of the yolk, fuse to form the *segmentation nucleus* which thus contains both male and female nuclear substance; the former transmits the individualities of the paternal, the latter those of the maternal ancestors, to the future embryo. By the union of the male and female pronuclei the number of chromosomes is restored to that present in the nuclei of the somatic cells.

FIG. 68.—First stages of segmentation of a mammalian ovum; semidiagrammatic. (From a drawing by Ailen Thomson.)



z.p. Zona striata. p.gl. Polar bodies. a. Two-cell stage. b. Four-cell stage. c. Eight-cell stage. d, e. Morula stage.

In some insects the primary oöcyte contains twenty-four chromosomes, and the primary spermatocyte, twenty-three. The mature ovum and the polar bodies each contain twelve chromosomes, while half the spermatozoa contain twelve, and the other half, eleven. It is maintained that if the mature ovum be fertilised by a spermatozoön with eleven chromosomes, the resulting embryo is a male, but if it be fertilised by a spermatozoön with twelve chromosomes, a female embryo is produced.

SEGMENTATION OF THE FERTILISED OVUM

The early segmentation of the human ovum has not yet been observed, but from what is known to occur in other mammals it may be regarded as certain that the process starts immediately after fertilisation, i.e. while the ovum is in the uterine tube. The segmentation nucleus exhibits the usual mitotic changes, and these are succeeded by a division of the fertilised ovum into two cells of nearly equal size.*

* In the mammalian ova the nutritive yolk or deuteroplasm is small in amount and uniformly distributed throughout the cytoplasm; such ova undergo *complete* division during the process of segmentation, and are therefore termed *holoblastic*. In the ova of birds, reptiles, and fishes, where the nutritive yolk forms by far the larger portion of the egg, the cleavage is limited to the formative yolk, and is therefore only *partial*; such ova are termed *meroblastic*. Again, it has been observed, in some of the lower animals, that the pronuclei do not fuse but merely lie in apposition. At the commencement of the segmentation process the chromosomes of the two pronuclei group themselves around the equator of the nuclear spindle and then divide; an equal number of male and female chromosomes travel to the opposite poles of the spindle, and thus the male and female pronuclei subscribe equal shares of chromatin to the nuclei of the two cells which result from the subdivision of the fertilised ovum.

The process is repeated again and again, so that the two cells are succeeded by four, eight, sixteen, thirty-two, and so on, with the result that a mass of cells is found within the zona striata, and to this mass the term *morula* is applied (fig. 68). The cells of the morula, at first closely aggregated, soon arrange themselves into an outer or peripheral layer, the *trophoblast*, which takes no part in the formation

FIG. 69.—Blastodermic vesicle of *Vespertilio murinus*. (After van Beneden.)

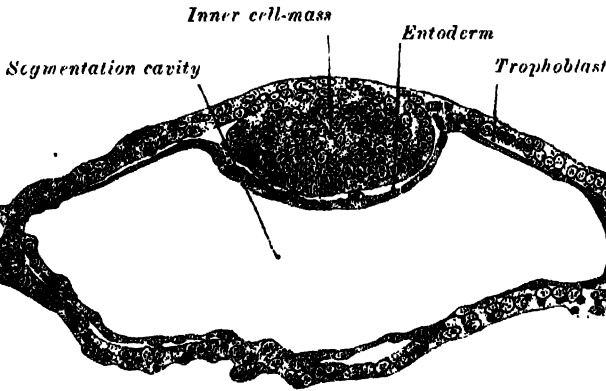


FIG. 70.—Section through embryonic disc of *Vespertilio murinus*. (After van Beneden.)

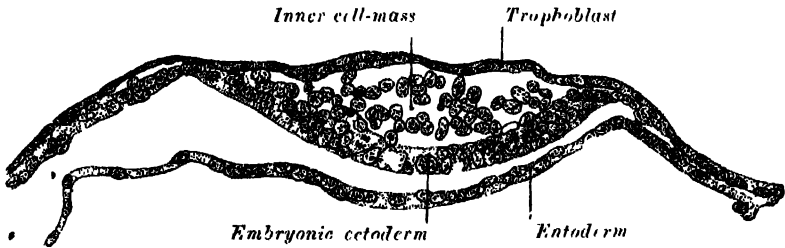
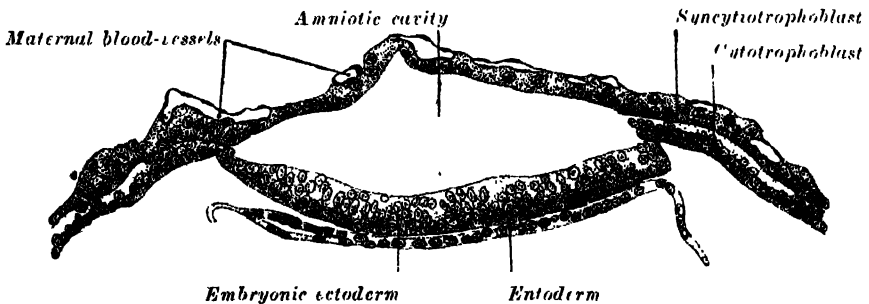


FIG. 71.—Section through embryonic disc of *Vespertilio murinus* to show the formation of the amniotic cavity. (After van Beneden.)



of the embryo proper, and an *inner cell-mass*, from which the embryo is developed. Fluid collects between the trophoblast and the greater part of the inner cell-mass, and thus the morula is converted into a vesicle which is named the *segmentation cavity* (fig. 69). The inner cell-mass remains in contact, however, with the trophoblast at one pole of the ovum; this is named the *embryonic pole*, since it indicates the situation where the future embryo will be developed. In the human ovum (figs. 72 to 74) the segmentation cavity is occupied by delicate strands of mesoderm

(magma réticulé or primitive mesoderm). The fibrils of the magma réticulé are continuous with those of the chorionic mesoderm, and its tissue is identical with the mesoderm of the chorion (Mall). Clefts appear in the magma réticulé and run together to form the *extra-embryonic cœlom*, which at first assumes the form of two slit-like clefts, one on either side of the embryonic disc (fig. 74).

The trophoblast differentiates into two strata: an outer, the *syncytium* or *syncytiotrophoblast*, consisting of a layer of protoplasm studded with nuclei, but showing no evidence of subdivision into cells; and an inner, the *cytotrophoblast* or *layer of Langhans*, in which the cell-outlines are defined. As already stated, the trophoblast takes no share in the formation of the embryo proper; it forms the ectoderm of the chorion and plays an important part in the imbedding of the ovum in the uterine mucous membrane, and in the development of the placenta. The inner cell-mass divides into a dorsal, ectodermal, and a ventral, entodermal, part. Spaces appear between the cells of each part and coalesce to form a cavity the

FIG. 72.—Diagram showing first differentiation of inner cell-mass.

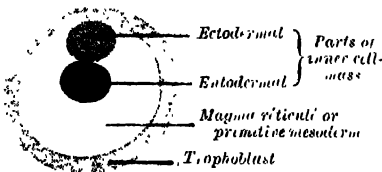


FIG. 73.—Diagram showing early stages in the formation of amnion and archenteron.

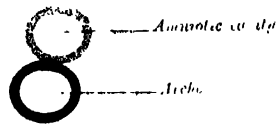
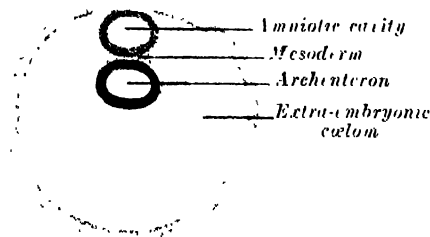


FIG. 74.—Diagram showing commencing formation of extra-embryonic cœlom.



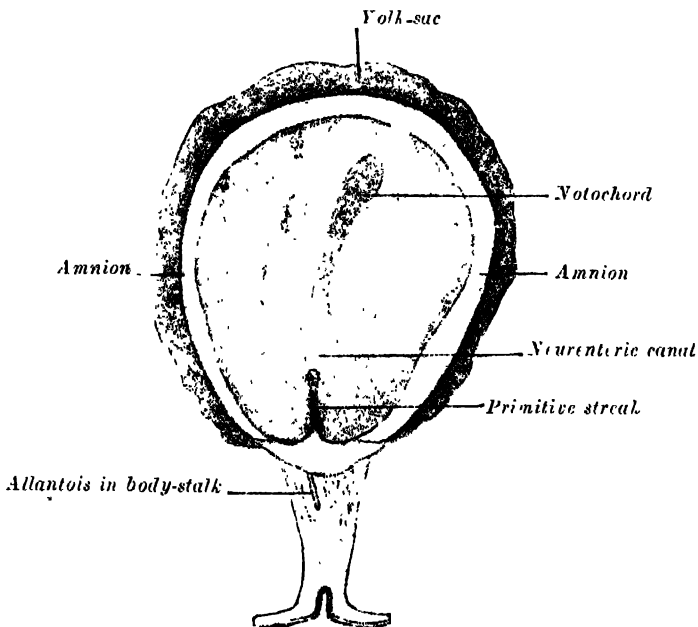
cavity in the ectodermal part is named the *amniotic cavity*, that in the entodermal part, the *archenteron* (figs. 72, 73). The floor of the amniotic cavity is formed by the *embryonic disc* composed of a layer of prismatic cells, the *embryonic ectoderm*, which is in apposition with the entoderm of the archenteron.

Formation of the mesoderm—the primitive streak.—The development of the mesoderm has not been observed in the human ovum, seeing that it is already present in the youngest human ova that have been examined. From what has been observed in other animals it may be concluded that the primitive streak is its principal source. The embryonic disc becomes oval and then pear-shaped. Near its narrow, posterior end an opaque streak, the *primitive streak* (fig. 75), makes its appearance and extends along the middle of the disc for a considerable part of its length; at the anterior end of the streak there is a knob-like thickening of the ectoderm termed *Hensen's knot*. A shallow groove, the *primitive groove*, appears on the surface of the streak, and the anterior end of this groove communicates with the archenteron through an aperture named the *blastopore*. The primitive streak is produced by a thickening of the axial part of the ectoderm, the cells of which multiply and blend with those of the subjacent entoderm (fig. 76, III, IV, V). From the primitive streak a third layer of cells, the *mesoderm*, extends between the ectoderm and entoderm.

The extension of the mesoderm takes place throughout the whole of the embryonic and extra-embryonic areas of the ovum, except in certain regions. One of these is seen immediately in front of the neural tube. Here the mesoderm grows forwards in the form of two crescentic masses, which meet in the middle line so as to enclose an area which is devoid of mesoderm. Over this area the ectoderm and entoderm are in contact with each other and constitute a thin membrane, the *buccopharyngeal membrane*, which forms a septum between the stomodæum or primitive mouth and the fore-gut or head-end of the primitive digestive tube. Where the lateral crescents of mesoderm meet in front of the buccopharyngeal membrane, the pericardium is afterwards developed, and this region is therefore designated the *pericardial area*. At the hind end of the embryo the ectoderm and entoderm are also in contact, and here they form the *cloacal membrane*.

The embryonic disc now consists of three layers, named from without inwards, ectoderm, mesoderm, and entoderm; each has distinctive characteristics and gives rise to certain tissues of the body.

FIG. 75.—Surface view of embryo of *Hylobates concolor*. (After Selenka.)
(From Quain's Elements of Anatomy, vol. i. Embryology.)



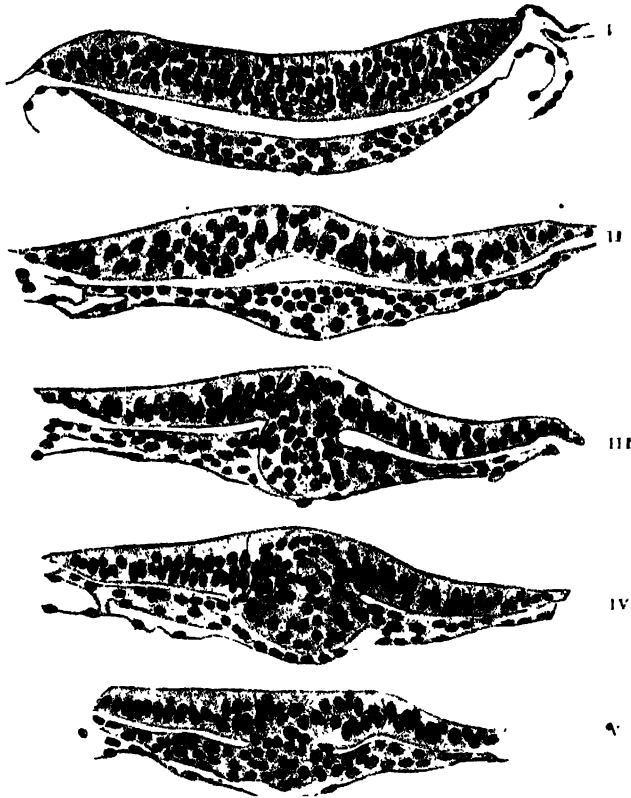
The amnion has been opened to expose the embryonic disc.

The **ectoderm** consists of columnar cells, which are, however, somewhat flattened or cubical towards the margin of the embryonic disc. It forms the whole of the nervous system, the epidermis of the skin, the lining cells of the sebaceous, sudoriferous and mammary glands, the hairs and nails, the epithelium of the nose and adjacent air-sinuses, and that of the cheeks and roof of the mouth. From it also are derived the anterior lobe of the hypophysis cerebri, the epithelium of the cornea, conjunctiva, and lacrimal glands, the neuro-epithelium of the sense-organs, and the enamel of the teeth.

The **entoderm** consists at first of flattened cells, which subsequently become columnar. It forms the epithelial lining of the whole of the digestive tube excepting part of the mouth and pharynx and the terminal part of the rectum (which are lined by involutions of the ectoderm), the lining cells of all the glands which open into the digestive tube, including those of the liver and pancreas, the epithelium of the auditory tube and tympanic cavity, of the trachea, bronchi, and air-cells of the lungs, of the urinary bladder and part of the urethra, and that which lines the follicles of the thyroid gland and thymus.

The **mesoderm** consists of loosely arranged branched cells surrounded by a considerable amount of intercellular fluid. From it the remaining tissues of the

FIG. 76.—Series of transverse sections through the embryonic disc of *Tarsius*. (After Hubrecht.) (From Quain's Elements of Anatomy, vol. i. Embryology.)

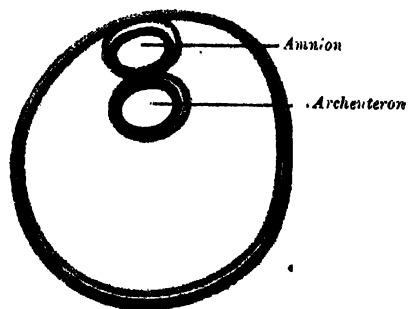


Section I passes through the disc, in front of Hensen's knot, and shows only the ectoderm and entoderm. Sections II, III, and IV pass through Hensen's knot, which is seen in V tapering away into the primitive streak. In III, IV, and V the mesoderm is seen springing from the keel-like thickening of the ectoderm, which in III and IV is observed to be continuous into the entoderm.

body are developed. The endothelial lining of the heart and blood-vessels and the blood-corpuscles are, however, regarded by some as being of entodermal origin.

As the mesoderm spreads between the ectoderm and entoderm it is separated for a time into lateral halves by the neural tube and notochord, presently to be described. A longitudinal groove appears on the dorsal surface of either half and divides it into the *paraxial mesoderm* which adjoins the neural tube and notochord, and is subsequently divided into the primitive segments, and a lateral portion, the *lateral mesoderm*. The mesoderm in the floor of the longitudinal groove between the paraxial and the lateral mesoderm, is known as the *intermediate cell-mass*; the genito-urinary organs are developed in it, and for this reason it is sometimes named the *nephrogenic cord*. The lateral mesoderm splits into two layers, an outer or *somatic*, which adheres to the inner surface of the

FIG. 77.—Diagram showing extension of mesoderm.

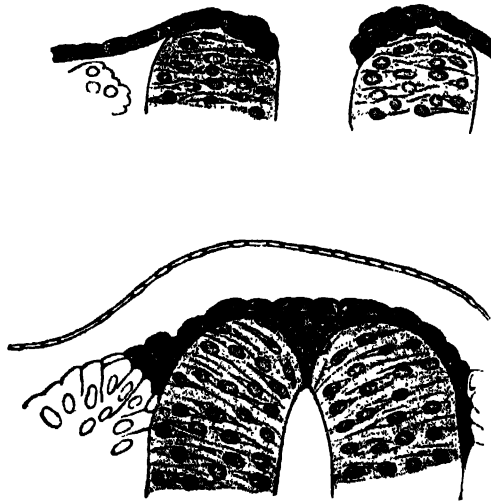


ectoderm, and with it forms the *somatopleure*; and an inner or *splanchnic*, which adheres to the entoderm, and with it forms the *splanchnopleure* (figs. 79, 82). The space between the two layers of the lateral mesoderm is termed the *cælon*.

THE NEURAL GROOVE AND TUBE

In front of the primitive streak two longitudinal ridges, caused by a thickening and upfolding of the ectoderm, make their appearance, one on either side of the middle line (fig. 79). These are named the *neural folds*; they commence near the anterior end of the embryonic disc, where they are continuous with each other, and gradually extend backwards, one on either side of the anterior end of the primitive streak. Between the neural folds is a shallow median groove, the *neural groove* (figs. 79, 80). This groove gradually deepens, and the edges of the folds meet and coalesce in the middle line and convert it into a closed tube, the *neural tube* or *canal* (fig. 82), the ectodermal wall of which forms the rudiment of the nervous system. By the coalescence of the neural folds over the anterior end of the primitive streak, the blastopore no longer opens on the surface but into the neural tube, and thus a transitory communication, named the *neurenteric canal*, is established between the neural and primitive digestive tubes. Closure of the neural groove occurs first in the region of the hind-brain, and from there extends forwards and backwards; towards the end of the third week the anterior opening (*anterior neuropore*) of the tube closes, and forms a recess which is in contact, for a time, with the overlying ectoderm; about the same time the posterior opening or *posterior neuropore* is closed. Subsequently the paraxial mesoderm grows round the neural tube, and separates it from the overlying ectoderm. Before the neural groove is closed a ridge of ectodermal cells appears along the prominent margin of each neural fold; this is termed the *neural crest* or *ganglion-ridge* (fig. 78), and from it the spinal and cerebral nerve-ganglia, the ganglia of the sympathetic nervous system, and the chromaffin bodies are developed.

FIG. 78.—Two stages in the development of the neural crest in the human body (Lenhossek.)

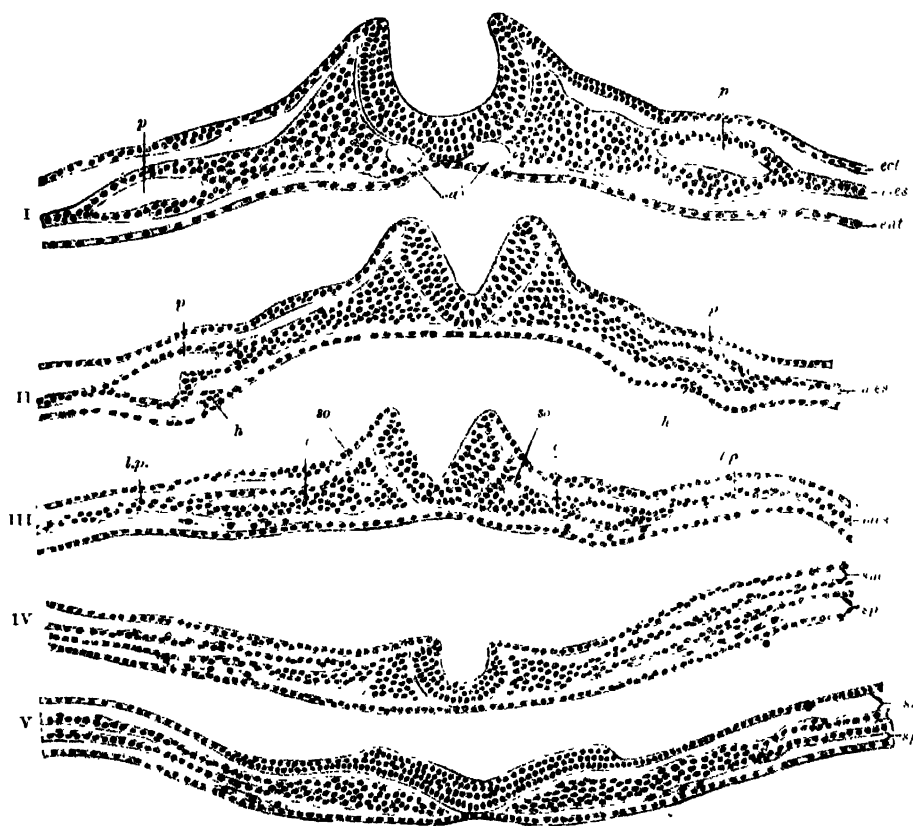


The cephalic end of the neural groove exhibits several dilatations, the cavities of which, when the tube is closed, assume the form of three vesicles; these constitute the three primary cerebral vesicles, and correspond respectively to the future *prosencephalon* (fore-brain), *mesencephalon* (mid-brain), and *rhombencephalon* (hind-brain) (fig. 81). The walls of the vesicles are developed into the nervous tissue and neuroglia of the brain, and the cavities of the vesicles are modified to form

the ventricles of the brain. The remainder of the neural tube forms the *medulla spinalis* or *spinal cord*; its ectodermal wall forms the nervous and neuroglial elements and its cavity the central canal of the medulla spinalis.

FIG. 79.—A series of transverse sections through an embryo of the dog. (After Bonnet.)
(From Quain's Elements of Anatomy, vol. i., Embryology.)

Section I is the most anterior. In V the neural plate is spread out nearly flat. The series shows the uprising of the neural folds to form the neural canal.



a., aorta; *c.*, intermediate cell-mass; *ect.*, ectoderm; *ent.*, entoderm; *h.*, rudiments of endodermal heart-tubes. In III, IV, and V the scattered cells represented between the ectoderm and Bonnet, to the heart-tubes *h*; *l.p.*, lateral plate still undivided in I, II, and III; in IV and V split into somatic (*sm*) and splanchnic (*sp*) layers of mesoderm; *mes.*, mesoderm; *p.*, pericardium; *so.*, primitive segment.

THE NOTOCHORD

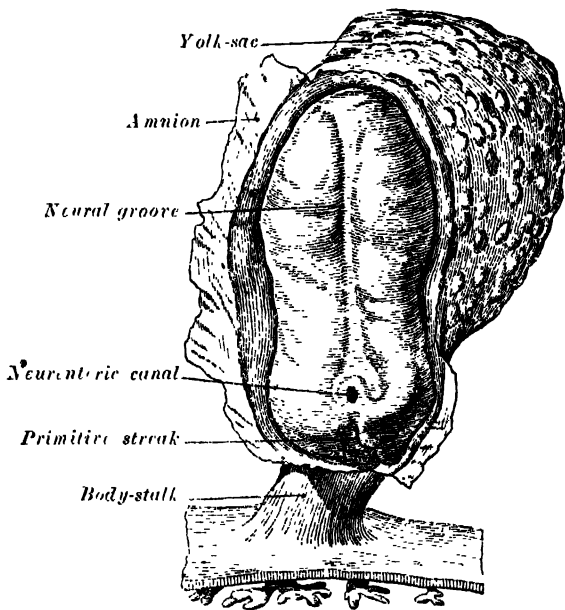
The **notochord** (fig. 82) constitutes the foundation of the axial skeleton, since around it the segments of the vertebral column are formed; its appearance synchronises with that of the neural tube. It grows forwards as a rod of cells from the anterior end of the primitive streak, and is at first intimately connected with the entoderm underlying the neural groove. It soon separates from the entoderm, and the separation is later emphasised by the mesoderm which grows medialwards and surrounds it. When fully formed it extends throughout the length of the future vertebral column, and its cephalic end reaches as far as the anterior part of the mid-brain, where it ends in a hook-like extremity in the region of the future dorsum sellæ of the sphenoidal bone. From the mesoderm surrounding the neural tube and notochord, the skull, the vertebral column, and the membranes of the brain and medulla spinalis are developed.

THE PRIMITIVE SEGMENTS

Towards the end of the second week transverse segmentation of the paraxial mesoderm begins, and converts it into a series of well-defined, more or less cubical masses, the *primitive segments* (figs. 81, 82, and 83), which extend from the occipital region of the skull along the entire length of the trunk on either side of the middle line. Each segment contains a central cavity (*myocœl*) which, however, is soon filled with angular and spindle-shaped cells.

The primitive segments lie immediately under the ectoderm on the lateral aspect of the neural tube and notochord, and are connected to the lateral mesoderm by the *intermediate cell-mass*. Those of the trunk are divisible into the following groups, viz. : cervical 8, thoracic 12, lumbar 5, sacral 5, and coccygeal from 5 to 8. Those of the occipital region of the head are usually described as being four in number. In mammals primitive segments of the head can only be recognised in the occipital region, but a study of the lower vertebrates leads to the belief that they are present also in the anterior part of the head, and that altogether nine segments are represented in the cephalic region.

FIG. 80.--Human embryo—length 2 mm. Dorsal view, with the amnion laid open. $\times 30$. (After Graf Spee.)



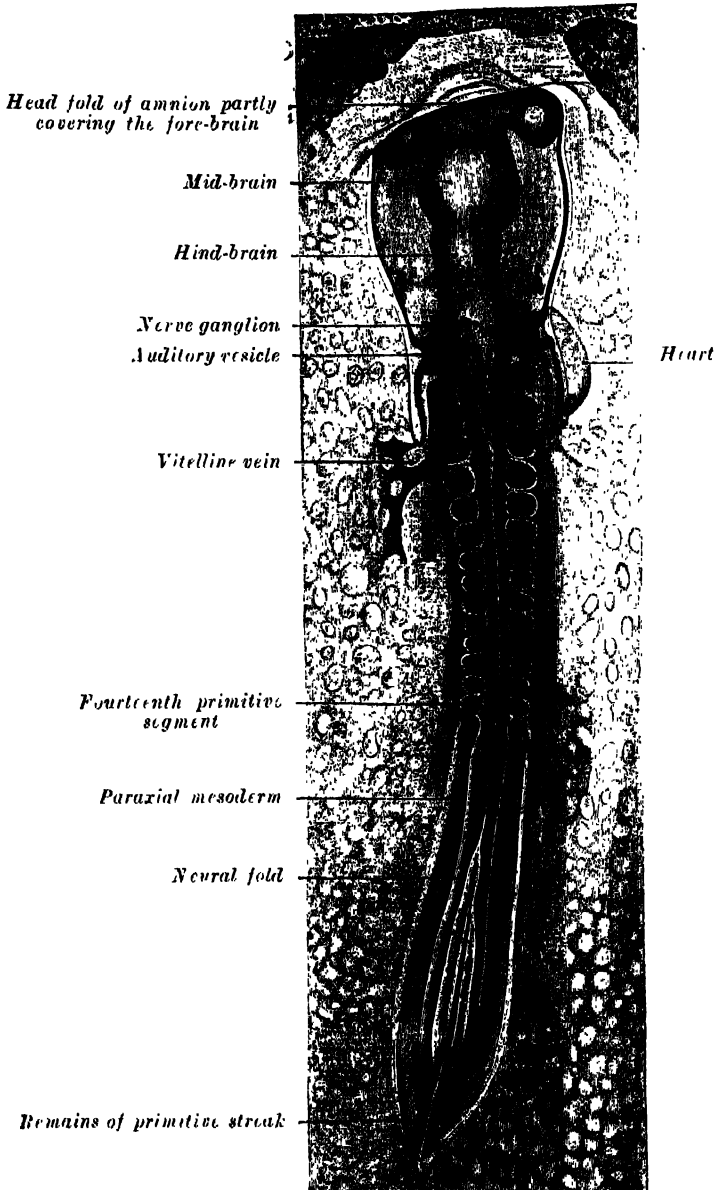
FORMATION OF THE EMBRYO

The embryo increases rapidly in size, but the circumference of the embryonic disc, or line of meeting of the embryonic and amniotic parts of the ectoderm, is of relatively slow growth and gradually forms a constriction between the embryo and the greater part of the archenteron. By means of this constriction, which corresponds to the future umbilicus, the dorsal part of the archenteron is enclosed within the embryo and constitutes the *primitive digestive tube*; the ventral part is left outside the embryo and constitutes the *yolk-sac*.

The embryo grows more rapidly in length than in width, and its cephalic and caudal ends bend in a ventral direction to form the *cephalic* and *caudal folds* respectively (figs. 89 and 90). The cephalic fold is first formed, and the forward growth of the head necessarily carries with it the posterior end of the pericardial area, so

that this area and the buccopharyngeal membrane are folded under the head of the embryo. A diverticulum of the archenteron, named the *fore-gut*, is enclosed in the cephalic fold. The caudal end of the embryo is connected to the chorion by a band of mesoderm called the *body-stalk*, but with the continued growth of this

FIG. 81.—Chick embryo of thirty-three hours' incubation, viewed from the dorsal aspect. $\times 30$. (From Duval's Atlas d'Embryologie.)

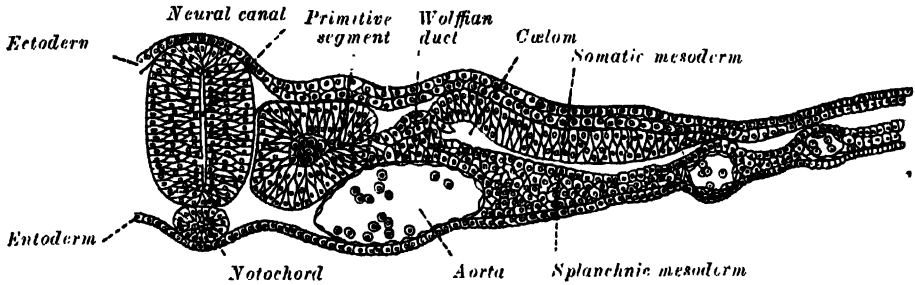


end and the formation of the caudal fold the body-stalk assumes a ventral position ; a diverticulum of the archenteron extends into the caudal fold and is termed the *hind-gut*. Between the fore-gut and the hind-gut there exists for a time a wide opening into the yolk-sac, but the relatively slow growth of the latter reduces it to a small pear-shaped sac (sometimes termed the *umbilical vesicle*), and the channel of communication is at the same time elongated to form a narrow tube called the *vitelline duct*.

THE YOLK-SAC

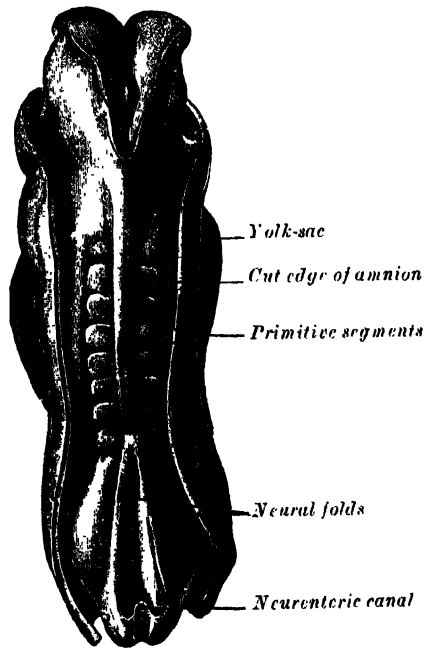
The **yolk-sac** (figs. 84 and 85) is situated on the ventral aspect of the embryo ; it is lined by entoderm, outside of which is a layer of mesoderm. It is filled with *vitelline fluid*, which is possibly utilised for the nourishment of the embryo during

FIG. 82.—Transverse section of a chick embryo of forty-five hours' incubation. (Balfour.)



the earlier stages of its existence. Blood is conveyed to the wall of the sac by the ventral branches of the primitive aortæ, and, after circulating through a wide-meshed capillary plexus, is returned by the vitelline veins to the tubular heart of the embryo. By means of this circulation nutritive material is absorbed from the yolk-sac and conveyed to the embryo. At the end of the fourth week the yolk-sac presents the

FIG. 83.—Dorsum of human embryo, 2.11 mm. in length. (After Ebernöl.)



appearance of a small pear-shaped vesicle (umbilical vesicle) opening into the digestive tube by a long narrow tube, the *vitelline duct*. The vitelline duct loses its attachment to the digestive tube, and as a rule undergoes complete obliteration during the seventh week, but in about two per cent. of cases its proximal part persists as a diverticulum (*Meckel's diverticulum*) from the small intestine, situated

about one metre above the ileocolic junction, and sometimes attached by a fibrous cord to the abdominal wall at the umbilicus. A narrowing of the lumen of the ileum is occasionally found opposite the site of attachment of the duct.

FIG. 84.—Section through the embryo which is represented in fig. 80.
(After Graf Spee.)

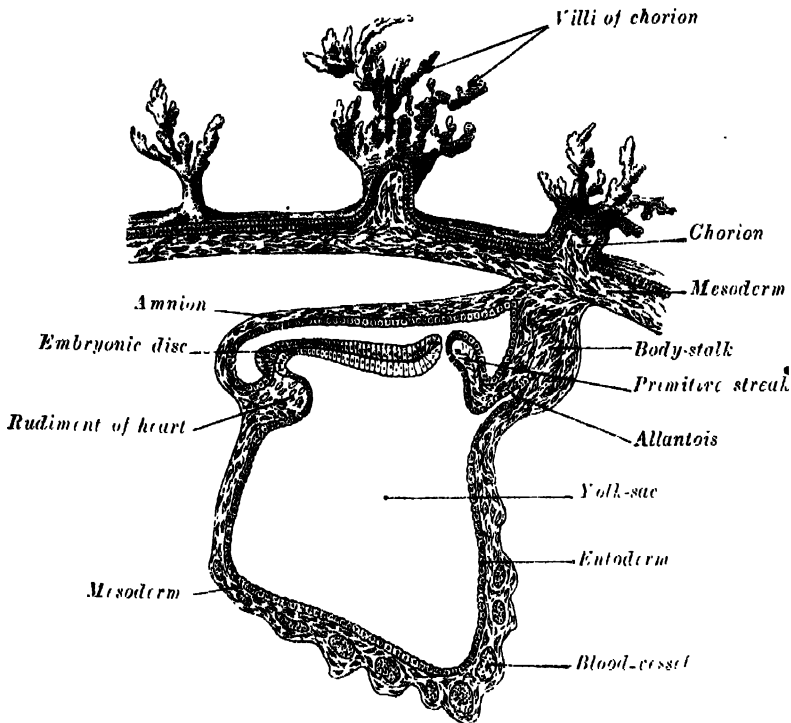
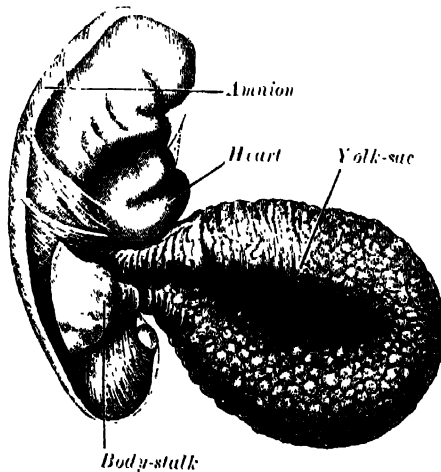


FIG. 85.—Human embryo of 2.6 mm. (His.)

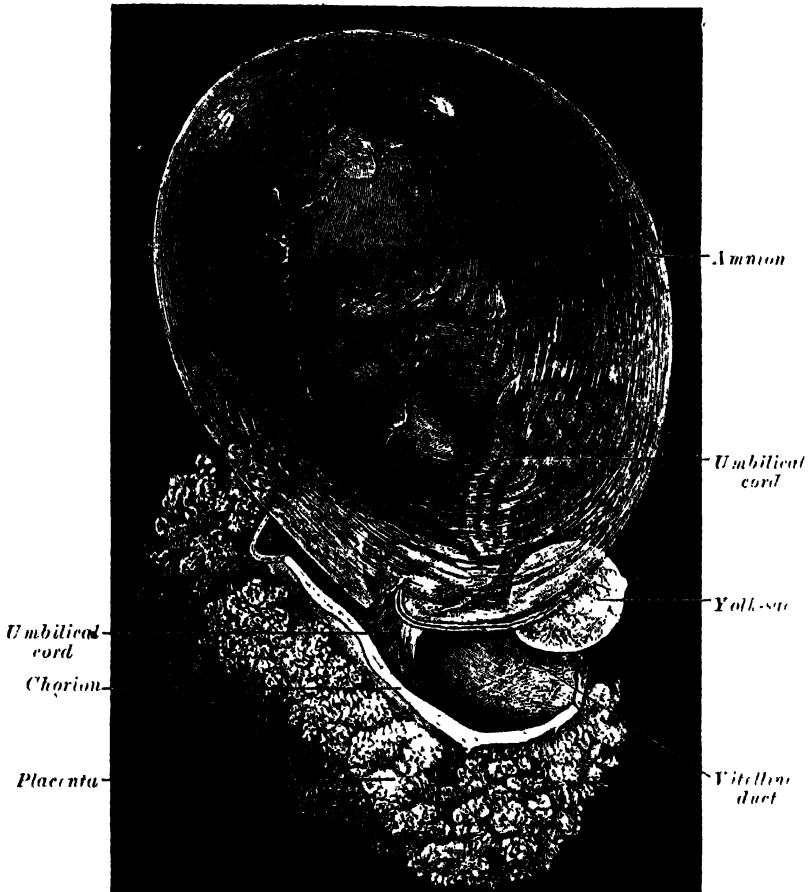


The umbilical vesicle can be seen in the after-birth as a small somewhat oval-shaped body with a diameter of from 1 to 5 mm. : it is situated between the amnion and the chorion, and may lie on, or at a variable distance from, the placenta.

FŒTAL MEMBRANES AND THE PLACENTA

The allantois (figs. 84, 89, 90).—The allantois arises as a tubular diverticulum of the posterior part of the archenteron ; when the hind-gut is developed the allantois is carried backwards with it, and then opens from the cloaca or terminal part of

FIG. 86.—Fœtus of about eight weeks, enclosed in the amnion. Magnified a little over 2 diameters. Drawn from stereoscopic photographs lent by Prof. A. Thomson, Oxford.



the hind-gut : it extends into the mesoderm of the body-stalk which connects the tail end of the embryo with the chorion. The allantoic diverticulum is lined by entoderm and covered by mesoderm, and in the latter are umbilical vessels.*

* In reptiles, birds, and many mammals the allantois expands into a vesicle which projects into the extra-embryonic coelom. If its further development be traced in the bird, it is seen to project to the right side of the embryo, and, gradually expanding, spreads over the dorsal surface of the embryo as a flattened sac between the amnion and the serosa (p. 61*), and ultimately surrounds the yolk. Its outer wall becomes applied to, and fuses with, the serosa, which lies immediately inside the shell membrane. Blood is carried to the allantoic sac by the two allantoic or umbilical arteries, which are continuous with the primitive aortae, and after circulating through the allantoic capillaries, is returned to the primitive heart by the two umbilical veins. In this way the allantoic circulation, which is of the utmost importance in connexion with the respiration and nutrition of the chick, is established. Oxygen is taken from, and carbonic acid is given up to the atmosphere through the egg-shell, and nutritive materials are at the same time absorbed by the blood from the yolk. With the formation of the amnion the embryo is, in most animals, entirely separated from the chorion, and is only again united to the chorion when the allantoic mesoderm spreads over and becomes applied to its inner surface ; but the human embryo, as was pointed out by His, is never wholly separated from the chorion, its tail end being from the first connected with the chorion by means of a thick band of mesoderm, named the *body-stalk* (Bauchstiel).

FIG. 87.—Diagram showing earliest observed stage of human ovum.

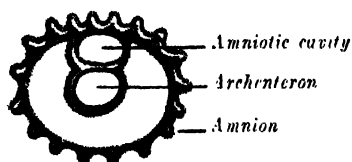


FIG. 88.—Diagram illustrating early formation of allantois and differentiation of body-stalk.

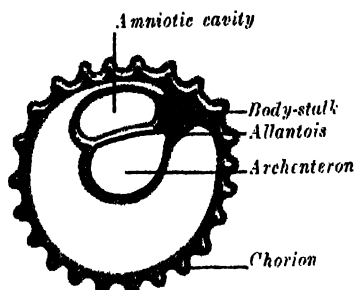


FIG. 89.—Diagram showing later stage of allantoic development with commencing separation of the yolk-sac.

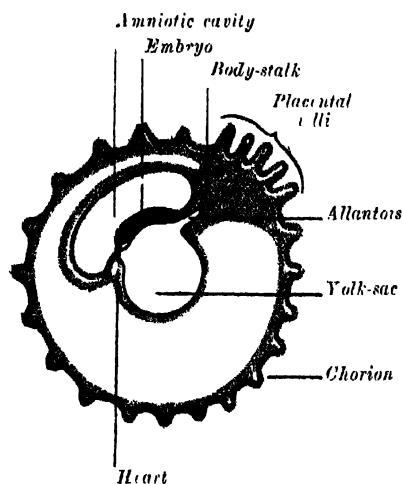


FIG. 90.—Diagram showing the expansion of amnion and delimitation of the umbilicus.

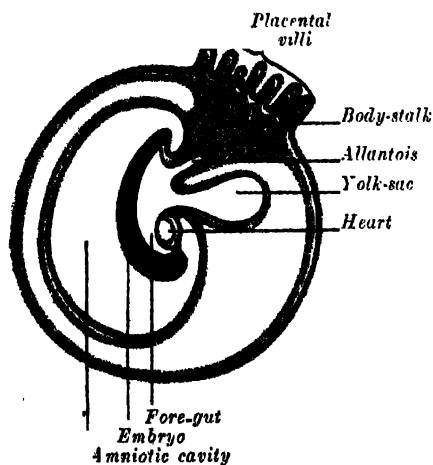
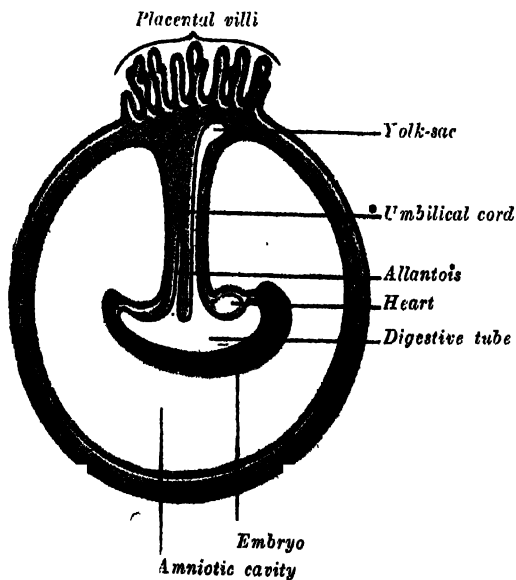


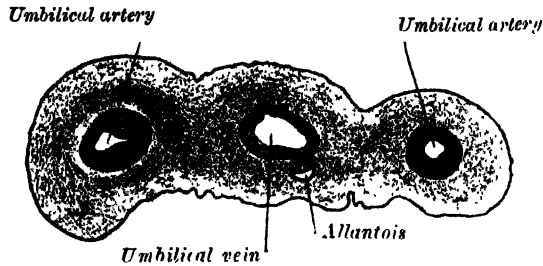
FIG. 91.—Diagram illustrating a later stage in the development of the umbilical cord.



The **amnion** is a membranous sac which surrounds and protects the embryo ; it is developed in reptiles, birds, and mammals, but not in amphibia and fishes.

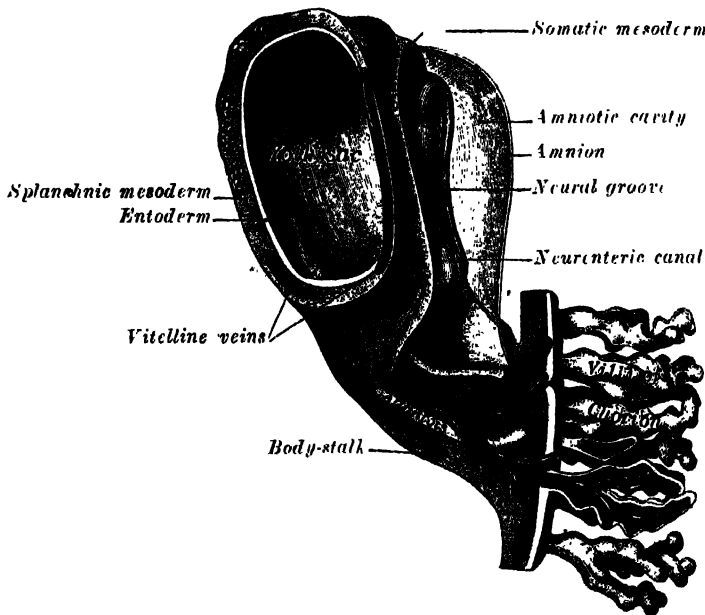
In the human embryo the earliest stages of the formation of the amnion have not been observed ; in the youngest embryo which has been studied the amnion was

FIG. 92.—Transverse section of umbilical cord.



already present as a closed sac (figs. 87 and 94), and, as indicated on page 50, appears as a cavity in the ectodermal part of the inner cell-mass. This cavity is roofed in by a stratum of flattened ectodermal cells, the *amniotic ectoderm*, and its floor consists of the prismatic ectoderm of the embryonic disc—the continuity between the roof and floor being established at the margin of the embryonic disc.

FIG. 93.—Drawing of a model of a human embryo 1·3 mm. long. (After Eternod.)



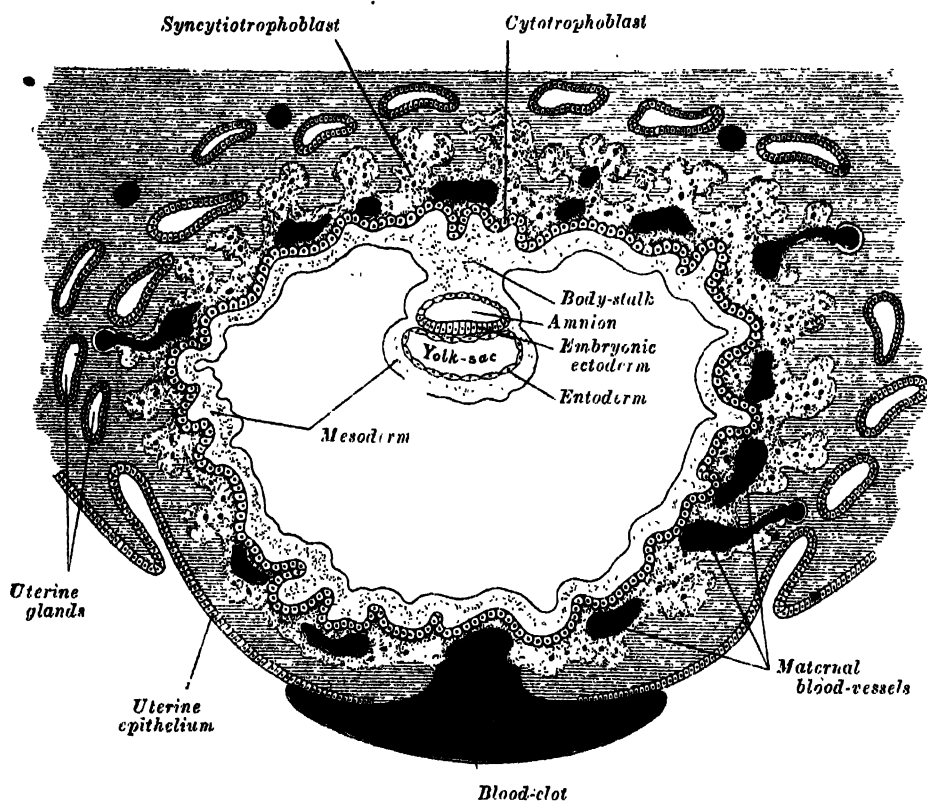
Outside the amniotic ectoderm is a thin layer of mesoderm, continuous with that of the somatopleure and connected by means of the body-stalk with the mesodermal lining of the chorion.*

* In reptiles, birds, and many mammals the amnion is developed as follows:—At the constriction where the primitive digestive tube of the embryo joins the yolk-sac, a reflection or upfolding of the somatopleure takes place. This, the *amniotic fold*, first makes its appearance at the cephalic end, and subsequently at the caudal end and sides of the embryo, and gradually rising more and more its different parts meet and fuse over the dorsal surface of the embryo, and enclose a cavity, the *amniotic cavity*. After the fusion of the edges of the amniotic fold, the two layers of the fold separate; the inner forms the *amnion*, the outer, the *false amnion* or *serosa*. The space between the amnion and the serosa constitutes the extra-embryonic coelom, and for a time communicates with the embryonic coelom.

EMBRYOLOGY

Fluid, termed *liquor amnii*, appears within the amniotic cavity and increases steadily in amount, so that the sac gradually expands and encroaches on the cavity of the extra-embryonic coelom; this expansion continues until the extra-embryonic coelom is obliterated. The liquor amnii increases in quantity up to the sixth or seventh month of pregnancy, and then diminishes somewhat; at the end of pregnancy it amounts to about 1 litre. It allows of the free movements of the foetus during the later stages of pregnancy, and also protects it by diminishing the risk of injury from without. It contains less than two per cent. of solids, consisting of urea and other extractives, inorganic salts, a small amount of protein, and frequently a trace of sugar.

FIG. 91.—Section through an ovum imbedded in the uterine decidua. Semidiagrammatic. (After Peters.)

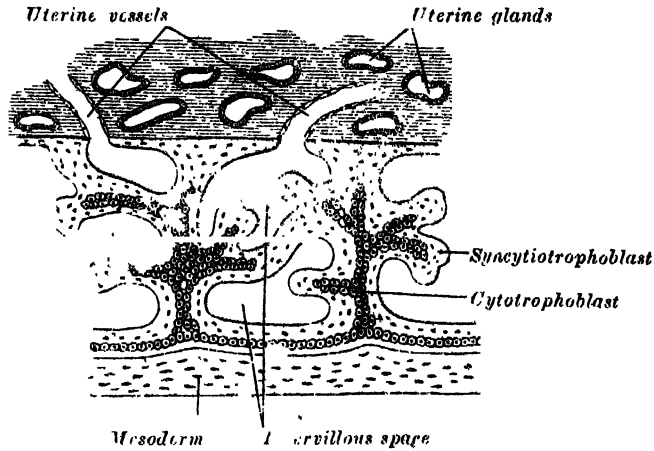


The body-stalk and umbilical cord.—The body-stalk (figs. 84, 89, 90, 93) is a band of mesoderm which from the first connects the tail end of the embryo with the chorion. Extending into the proximal part of it is the canal of the allantois, and running through it from the embryo to the chorion are the umbilical vessels. Its dorsal surface is covered by the amnion and its ventral surface is bounded by the extra-embryonic coelom. As a result of the folding of the embryo and the distension of the amnion the body-stalk comes to lie on the ventral surface of the embryo, and its mesoderm approaches that of the yolk-sac and vitelline duct (fig. 90). As a consequence of the continued expansion of the amnion the extra-embryonic coelom is obliterated (figs. 90, 91), the vitelline duct is elongated, and the mesoderm of the amnion blends with that of the vitelline duct and body-stalk; by this fusion a solid cord, the *umbilical cord*, is formed (fig. 91) and connects the embryo to that portion of the chorion which will form the foetal part of the placenta.

The umbilical cord (figs. 92, 100) is enveloped by the amniotic ectoderm and consists of a core of gelatinous tissue (jelly of Wharton) in which the umbilical vessels, the allantoic diverticulum, and the vitelline duct and vessels are imbedded.

The allantoic diverticulum and the vitelline duct and vessels undergo obliteration and atrophy, but traces of them may be seen up to the fourth month or later. The umbilical cord becomes spirally twisted, owing, it is believed, to the unequal growth

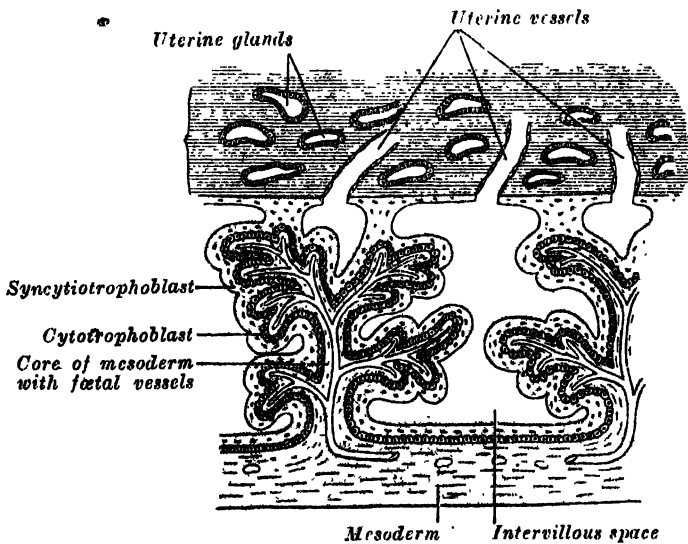
FIG. 95.—Primary chorionic villi. (Diagrammatic.) (Modified from Bryce.)



of the two umbilical arteries, it also increases in length so that at the end of pregnancy it averages about 50 cm

Implantation or imbedding of the fertilised ovum in the uterine wall.—As already stated (page 47), fertilisation of the ovum is believed to occur in the lateral or ampullary end of the uterine tube, and is immediately followed by segmentation. The segmenting ovum is conveyed along the uterine tube to the cavity of the uterus,

FIG. 96.—Secondary chorionic villi. (Diagrammatic.) (Modified from Bryce.)

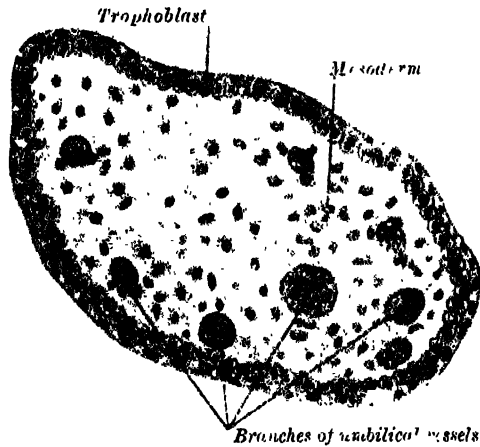


the journey occupying seven or eight days. By the time it reaches the uterus it possesses a well-developed trophoblast. The ovum adheres like a parasite to the uterine mucous membrane, destroys the epithelium over the area of contact, and excavates for itself a cavity in the mucous membrane in which it becomes imbedded.

In an ovum described by Bryce and Teacher* the point of entrance of the ovum into the uterine mucous membrane was visible as a small gap closed by a mass of fibrin and leucocytes; in an ovum described by Peters† the opening was covered by a mushroom-shaped mass of fibrin and blood-clot (fig. 94), the narrow stalk of which plugged the aperture in the mucous membrane. Soon, however, all trace of the opening is lost, and the ovum is then completely surrounded by the uterine mucous membrane.

The structure actively concerned in excavating the uterine mucous membrane is the trophoblast. This increases rapidly in thickness, invades and digests the uterine tissues, destroys the epithelial cells of the uterine glands and the walls of the uterine (maternal) blood-vessels (fig. 94); at the same time there appear in the trophoblast numerous anastomosing spaces which are filled with maternal blood. These spaces expand to form what is ultimately known as the *intervillous space*, and the trophoblast is separated into a number of branching processes named the

FIG. 97.—Transverse section of a chorionic villus.



primary chorionic villi (fig. 95) which are bathed in the maternal blood. Cores of mesoderm, containing branches of the umbilical vessels, soon invade these primary villi and convert them into *secondary chorionic villi* (figs. 96, 97).

The decidua.—Before the fertilised ovum reaches the uterus, the mucous membrane of the body of the uterus undergoes important changes, and is then known as the *decidua*. The thickness and vascularity of the mucous membrane are greatly increased; its glands are elongated and open on its free surface by funnel-shaped orifices, while their deeper portions are tortuous and dilated into irregular spaces. The interglandular tissue is also increased in quantity, and is crowded with large round, oval, or polygonal cells, termed *decidual cells*. These changes are well advanced by the second month of pregnancy, when the mucous membrane consists of the following strata (fig. 98): (1) *stratum compactum*, next the free surface; in this the uterine glands are only slightly expanded, and are lined by columnar cells; (2) *stratum spongiosum*, where the uterine glands are greatly dilated and very tortuous, and are ultimately separated from one another by only a small amount of interglandular tissue; for a time the cells lining the glands are cylindrical, but later they become flattened; (3) a thin *limiting or boundary layer*, next the uterine muscular fibres, containing the deepest parts of the uterine glands, which are not dilated, and are lined with cubical epithelium; it is from this epithelium that the epithelial lining of the uterus is regenerated after pregnancy.

* Contribution to the study of the early development and imbedding of the human ovum, 1909.

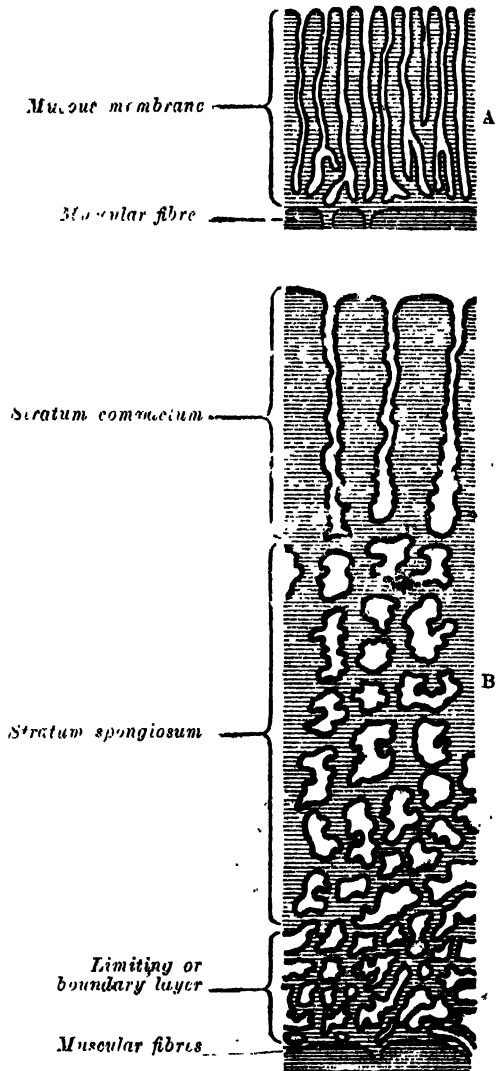
† *Einbettung des menschlichen Eies*, 1899.

After the ovum is imbedded distinctive names are applied to different portions of the decidua. The part which covers in the ovum is named the *decidua capsularis*; the portion between the ovum and the uterine muscular wall is named the *decidua basalis* or *decidua placentalis*; it is here that the placenta is subsequently developed; the part which lines the remainder of the body of the uterus is known as the *decidua vera* or *decidua parietalis*.

Coincidentally with the growth of the embryo, the decidua capsularis is thinned and distended (fig. 99) and the space between it and the decidua vera is gradually obliterated. By the beginning of the third month of pregnancy the decidua capsularis and decidua vera are in contact; by the fifth month of pregnancy the decidua capsularis has practically disappeared, while during the succeeding months the decidua vera also undergoes atrophy, owing to the increased pressure. The glands of the stratum compactum are obliterated, and their epithelium is lost; in the stratum spongiosum the glands are compressed and appear as slit-like fissures, and their epithelium undergoes degeneration in the limiting or boundary layer; however, the glandular epithelium retains a cubical form.

The chorion (figs. 89 to 93 and 95 to 97).—The chorion consists of two layers: an outer of trophoblast, and an inner of mesoderm. The trophoblast consists of an internal layer, the *cytotrophoblast* or *layer of Langhans*, and an external layer, the *syncytiotrophoblast*. As stated (page 64) it undergoes rapid proliferation and forms, on the surface of the chorion, numerous processes, the *primary chorionic villi* (fig. 95); these increase in size and ramify, and the chorionic mesoderm, carrying branches of the umbilical vessels, grows into them, and in this way they are converted into *secondary chorionic villi* (fig. 96). Blood is carried from the embryo to the chorion by the umbilical arteries, and after circulating through the capillaries of the villi, is returned to the embryo by the umbilical veins. Until about the end of the second month of pregnancy the villi cover the entire chorion, are almost uniform in size, and project into the decidua placentalis and decidua capsularis (fig. 99). With the growth of the embryo and the expansion of the amniotic cavity the decidua capsularis is thinned and compressed, the circulation through it is gradually cut off, and the villi of the corresponding part of the chorion atrophy and disappear. This portion of the chorion becomes smooth (*chorion laeve*); and, as it takes no share in the formation of the placenta, is sometimes named the non-placental part of the chorion. On the other hand, the villi on that

FIG. 98.—Diagrammatic sections of the uterine mucous membrane; (A) of the non-pregnant uterus; (B) of the pregnant uterus, showing the thickened mucous membrane and the altered condition of the uterine glands. (Kundrat and Engelmann.)

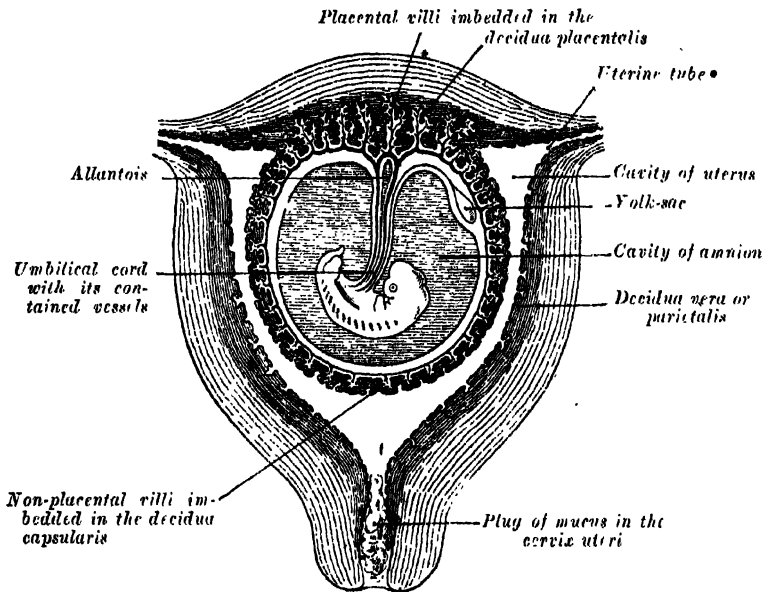


part of the chorion which is in contact with the decidua placentalis increase greatly in size and complexity, and hence this part is named the *chorion frondosum* (figs. 90, 91).

The placenta (figs. 99 to 101).—The placenta connects the fetus to the uterine wall, and is the organ by means of which the nutritive, respiratory, and excretory functions of the fetus are carried on. It is composed of fetal and maternal parts.

The *fetal portion of the placenta* consists of the villi of the chorion frondosum which branch repeatedly, and increase enormously in size. The ends of some of them are anchored by columns of trophoblast to the walls of the intervillous space, but the majority hang free in this space. All are bathed in maternal blood, which is conveyed to and from the space by the uterine vessels. Blood is carried from the embryo to the placental villi by the umbilical arteries, and returned to the embryo by the umbilical veins. One or two branches of an artery enter each villus and there end in a capillary plexus which is drained by one or two tributaries of

FIG. 99.—Sectional plan of the gravid uterus in the third month.
(Modified from Wagner.)

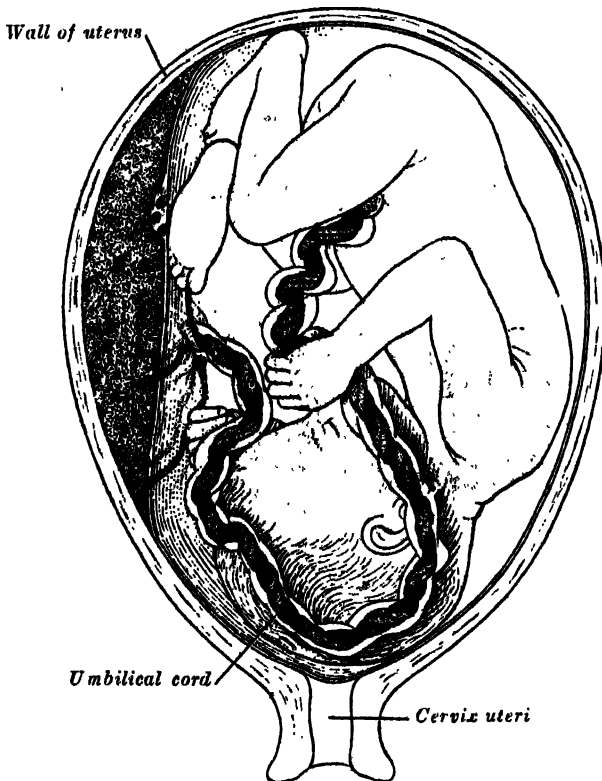


the veins. The vessels of the villi are surrounded by a thin layer of mesoderm which is covered by the two strata of the trophoblast, the cytotrophoblast or layer of Langhans being in contact with the mesoderm, and the syncytiotrophoblast in contact with the maternal blood (fig. 101). After the fifth month the two strata of cells are replaced by a single layer of somewhat flattened cells.

The *maternal portion of the placenta* is formed by the decidua placentalis containing the intervillous space. As already explained, this space is produced by the enlargement and intercommunication of the spaces in the trophoblast; it is therefore lined throughout by syncytiotrophoblast. The formation of the intervillous space involves the disappearance of the greater portion of the stratum compactum, but the deeper part of this layer persists and is condensed to form what is known as the *basal plate*; this constitutes the outer wall of the intervillous space, and consists of a stroma containing decidual cells, portions of trophoblast and *fibrinoid substance*; the last appears to be derived in part from the trophoblast and in part from the maternal blood. Between the basal plate and the uterine muscular fibres are the stratum spongiosum and the limiting layer; through these and the basal plate the uterine arteries and veins pass to and from the intervillous space. Portions of the stratum compactum persist as pillars which project into the intervillous space, but these pillars do not extend as far as the chorion, except in the marginal part of the placenta; later they form the *placental septa* which incompletely divide the placenta into lobes or *cotyledons*.

Maternal blood is conveyed to the intervillous space by branches of the uterine arteries and carried away by tributaries of the uterine veins (figs. 100, 101). These vessels lose their muscular coats as they enter the basal plate, in which they consist of sinuous channels lined only by endothelium; these channels open into the intervillous space, the arteries ending near the placental septa and the veins beginning near the centres of the cotyledons. The endothelial lining of the uterine vessels ends where the vessels open into the intervillous space which is lined throughout by syncytiotrophoblast. The circumferential part of the intervillous space consists of an irregular channel named the *marginal sinus* (fig. 101); this sinus partly encircles the placenta and communicates peripherally with the uterine veins, and centrally with the intervillous space; clusters of placental villi project into it.

FIG. 100.—Fœtus in utero, between fifth and sixth months.



The foetal and maternal blood-currents do not intermingle, being separated from each other by the delicate walls of the villi. Nevertheless, the foetal blood is able to absorb, through the walls of the villi, oxygen and nutritive materials from the maternal blood, and give up to the latter its waste products. The blood, so purified, is carried back to the foetus by the umbilical vein. It will thus be seen that the placenta not only establishes a mechanical connexion between the mother and the foetus, but subserves for the latter the purposes of nutrition, respiration, and excretion. In favour of the view that the placenta possesses certain selective powers may be mentioned the fact that glucose is more plentiful in the maternal than in the foetal blood. It is interesting to note also that the proportion of iron and of lime and potash in the foetus is increased during the last months of pregnancy. Further, there is evidence that the maternal leucocytes may migrate into the foetal blood, since leucocytes are much more numerous in the blood of the umbilical vein than in that of the umbilical arteries.

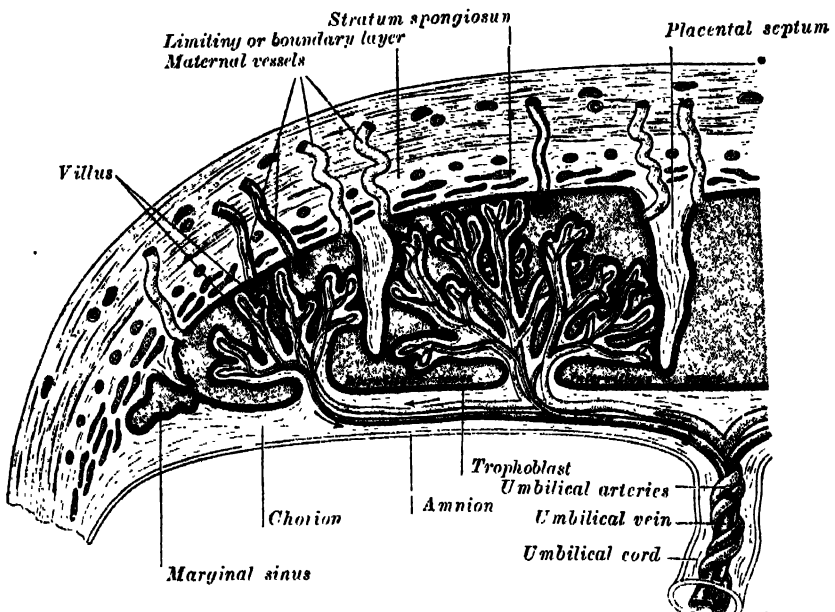
The placenta is usually attached near the fundus uteri, and its site corresponds with that at which the ovum is imbedded. It may, however, occupy a lower level,

and in very rare cases occludes the internal orifice of the uterus, thus giving rise to the condition known as *placenta prævia*.

Separation of the placenta.—After the child is born, the placenta and membranes (the latter consisting of the amnion, the chorion lœve and the superficial part of the decidua parietalis) are separated from the uterine wall and expelled as the *after-birth*. The separation takes place along the plane of the stratum spongiosum (fig. 101), and necessarily causes rupture of the uterine vessels. The orifices of the torn vessels are, however, closed by the firm contraction of the uterine muscular fibres, and thus *post-partum hæmorrhage* is prevented. After the separation of the placenta and membranes a thin layer of the stratum spongiosum is left as a lining to the uterus, but this layer subsequently undergoes degeneration, and is cast off. The mucous membrane, the glands and the epithelial lining of the uterus are regenerated from the limiting or boundary layer of the decidua (page 64).

The expelled placenta is a discoid mass which has a weight about 500 gm., a diameter of from 15 cm. to 20 cm., and an average thickness of about 3 cm., but

FIG. 101.—Scheme of placental circulation.



the thickness rapidly diminishes near the circumference of the disc, which is continuous with the membranes. Its uterine or outer surface is divided by a series of fissures into lobules or *cotyledons* which are imperfectly separated from one another by the placental septa. Its foetal or inner surface is smooth, and is closely invested by the amnion. Seen through the latter, the chorion presents a mottled appearance, consisting of grey, purple, or yellowish areas. The umbilical cord is usually attached near the centre of the placenta, but may be inserted anywhere between the centre and the margin; in some cases it is inserted into the membranes, i.e. the *velamentous* insertion. From the site of the attachment of the cord the larger branches of the umbilical vessels radiate under the amnion, the veins being deeper and larger than the arteries. The remains of the vitelline duct and yolk-sac may be sometimes observed beneath the amnion, close to the cord, the former as an attenuated thread, the latter as a minute sac.

On section, the placenta presents a soft, spongy appearance, caused by the greatly branched villi; surrounding them is a varying amount of maternal blood, giving the dark red colour to the placenta.

The further growth of the embryo will be best understood from a description of the principal facts relating to the development of the chief systems of which the body consists.

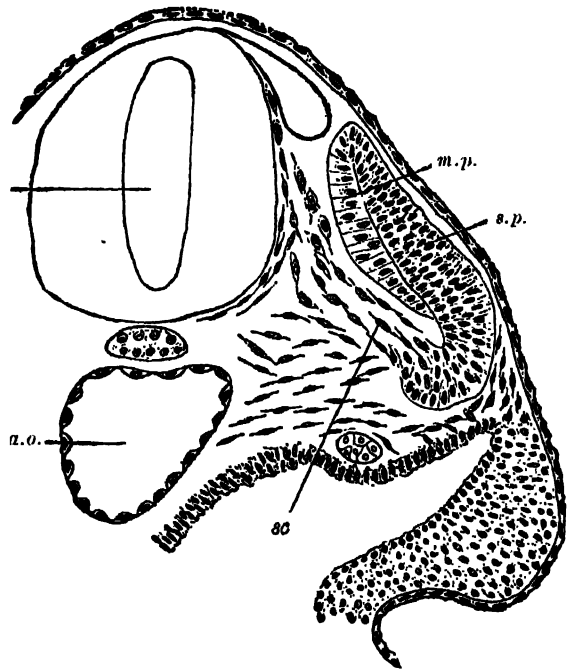
DEVELOPMENT OF THE PARIETES

The skeleton.—The skeleton is of mesodermal origin, and may be divided into (1) the axial skeleton, viz. that of the vertebral column, skull, ribs, and sternum, and (2) the appendicular skeleton, viz. that of the limbs.

The vertebral column.—The notochord (fig. 82) is a temporary structure and forms a central axis, around which the segments of the vertebral column are developed.* It is derived from the anterior end of the primitive streak, and, when fully formed, consists of a rod of cells, which lies on the ventral aspect of the neural tube and reaches from the anterior end of the mid-brain to the extremity of the tail. On either side of it is a column of paraxial mesoderm which becomes subdivided into a number of

more or less cubical segments, the *primitive segments* (figs. 81 and 83). These are separated from one another by *intersegmental septa* and are arranged symmetrically on either side of the neural tube and notochord: to every segment a spinal nerve is distributed. At first each segment contains a central cavity, the *myocœl*, but this is soon filled with a core of angular and spindle-shaped cells. The cells of the segment are differentiated into three groups, which form respectively the *cutis-plate* or *dermatome*, the *muscle-plate* or *myotome*, and the *sclerotome* (fig. 102). The *cutis-plate* is placed on the lateral and dorsal aspect of the *myocœl*, and from it the true skin of the corresponding segment is derived; the *muscle-plate* is situated on the medial side of the *cutis-plate*, and furnishes

FIG. 102.—Transverse section of a human embryo of the third week, to show the differentiation of the primitive segment. (Kollmann.)



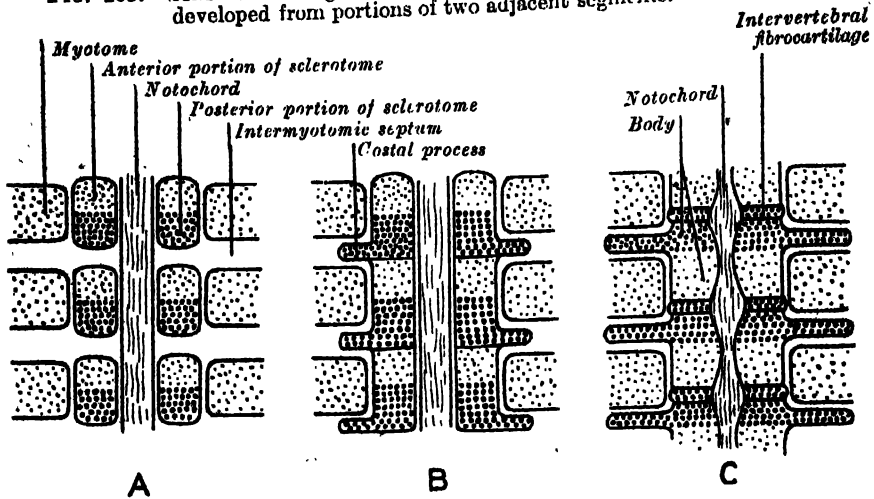
ao, aorta; m.p., muscle-plate; n.c., neural canal; sc., sclerotome; s.p., cutis-plate.

the muscles of the segment. The cells of the *sclerotome* are largely derived from those forming the core of the *myocœl*, and lie next the notochord. Fusion of the individual *sclerotomes* in an anteroposterior direction soon takes place, and thus a continuous strand of cells, the *scleratogenous layer*, is formed along the ventrolateral aspects of the neural tube. The cells of this layer proliferate rapidly, and extending medialwards surround the notochord; at the same time they grow backwards on the lateral aspects of the neural tube and eventually surround it, and thus the notochord and neural tube are enveloped by a continuous sheath of mesoderm (fig. 104), which is termed the *membranous vertebral column*. In this mesoderm the original *sclerotomes* are still distinguishable, but each is now differentiated into two portions, an anterior, consisting of loosely arranged cells, and a posterior, of more condensed tissue (fig. 103, A and B). Between the two portions the rudiment* of the intervertebral fibrocartilage is laid down (fig. 103, C). Cells from the posterior mass grow into the intervals between the *myotomes* (fig. 103, B and C) of the corresponding and succeeding segments, and extend both dorsally

* In *Amphioxus* the notochord persists and is the only representative of a skeleton in that animal.

and ventrally; the dorsal extensions surround the neural tube and represent the future vertebral arch, while the ventral extend into the body-wall as the costal processes. The hinder part of the posterior mass joins the anterior mass of the succeeding sclerotome to form the vertebral body. Each vertebral body is therefore

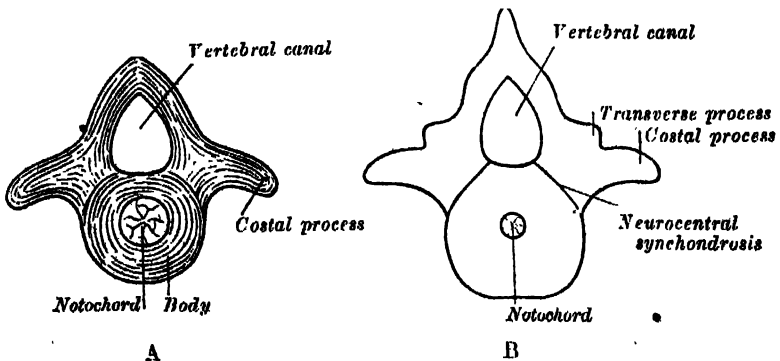
FIG. 103.—Scheme showing the manner in which each vertebral body is developed from portions of two adjacent segments.



a composite of two segments, being formed from the posterior portion of one and the anterior part of that immediately behind it. The vertebral and costal arches are derivatives of the posterior part of the segment in front of the intersegmental septum with which they are associated.

This stage is succeeded by that of the *cartilaginous vertebral column*. In the fourth week cartilaginous centres make their appearance on either side of the notochord; these extend round the notochord and form the bodies of the cartilaginous vertebrae. A pair of cartilaginous foci appear in the lateral parts of each vertebral arch, and grow backwards on either side of the neural tube to form the cartilaginous vertebral arch, and a separate cartilaginous centre appears for each costal process. In the eighth week the cartilaginous vertebral arch fuses with

FIG. 104.—Diagram showing (A) membranous and (B) cartilaginous stages of a typical vertebra.

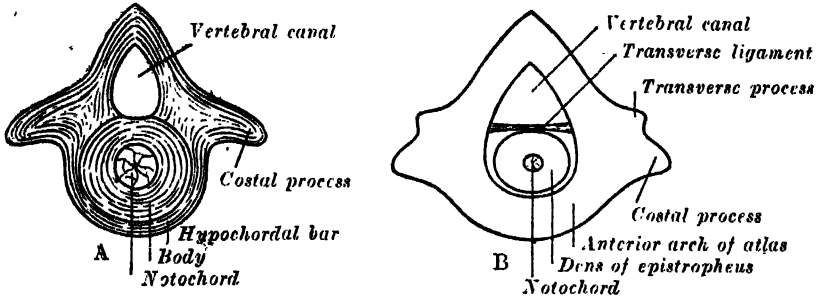


the cartilaginous body, and in the fourth month the halves of the arch unite on the dorsal aspect of the neural tube (fig. 104, B); the spinous process is developed from the junction of the halves of the vertebral arch. The transverse processes grow out from the vertebral arch behind the costal processes.

In the upper cervical vertebrae a band of mesodermal tissue connects the lateral extremities of the vertebral arches across the ventral surfaces of the intervertebral

fibrocartilages. This is termed the *hypochordal bar* or *brace* (fig. 105, A); in all except the atlas or first cervical vertebra it is transitory and fuses with the fibrocartilages. In the atlas, however, it persists, undergoes chondrification, and develops into the anterior arch of this bone, while the cartilage representing the body

FIG. 105.—Diagrams showing transformation of hypochordal bar into anterior arch of atlas.

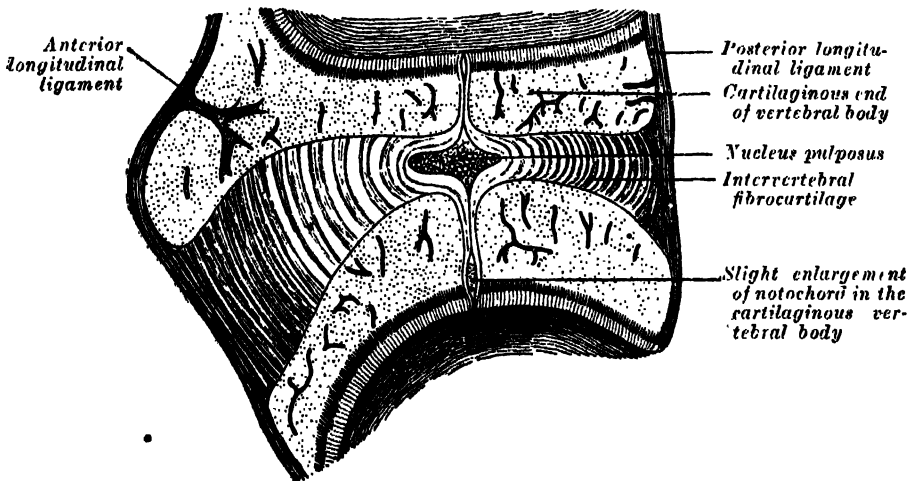


of the atlas forms the dens or odontoid process which fuses with the body of the second cervical vertebra (fig. 105, B).

The portions of the notochord contained within the bodies of the vertebrae atrophy, and ultimately disappear, while those which lie in the centres of the intervertebral fibrocartilages expand, and persist throughout life as the central *nucleus pulposus* of the fibrocartilages (fig. 106).

The ribs.—The ribs are formed from the costal processes of the primitive vertebral arches, the processes extending between the muscle-plates. In the *thoracic region* of the vertebral column the costal processes grow lateralwards to form a series of arches, the *primitive costal arches*. The transverse process grows out behind the vertebral end of the costal process, and is at first connected to this process by mesoderm which is later differentiated to form the costotransverse ligaments; between the costal process and the tip of the transverse process the costotransverse

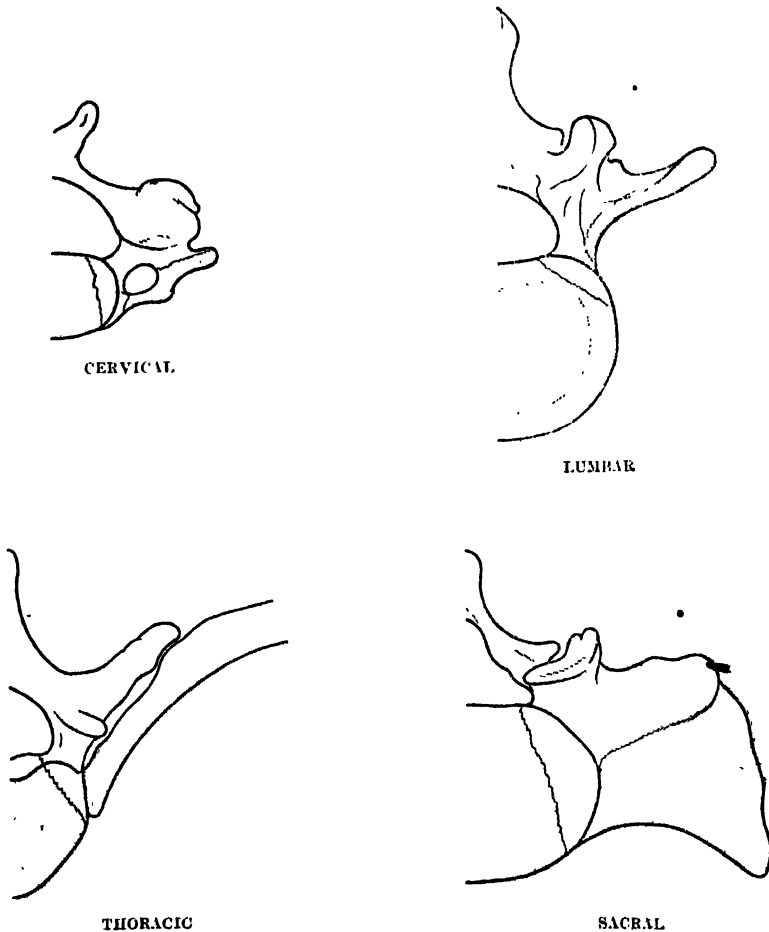
FIG. 106.—Sagittal section through an intervertebral fibrocartilage and adjacent parts of two vertebrae of a sheep's embryo. (Kölliker.)



joint is formed by absorption, while the proximal end of the costal process becomes separated from the vertebral arch by the development of the costocentral joint. In the *cervical vertebrae* (fig. 107) the transverse process forms the posterior boundary of the foramen transversarium, while the costal process, corresponding to the head and neck of the rib, remains in continuity with the body of the vertebra, and forms the anterolateral boundary of this foramen. The distal portions of the primitive

costal arches remain undeveloped ; occasionally, however, the costal processes of the seventh cervical vertebra undergo greater development, and by the formation of costovertebral joints are separated off as ribs. In the *lumbar region* the distal portions of the primitive costal arches fail ; the proximal portions fuse with the transverse processes to form the transverse processes of descriptive anatomy. Occasionally a movable rib is developed in connexion with the first lumbar vertebra. In the *sacral region* costal processes are developed only in connexion with the upper

FIG. 107.—Diagrams showing the portions of the adult vertebra derived respectively from the bodies, vertebral arches, and costal processes of the embryonic vertebrae.



The bodies are represented in yellow, the vertebral arches in red, and the costal processes in blue.

three or four vertebrae ; the processes of adjacent segments fuse with one another to form the lateral parts of the sacrum. The *coccygeal vertebrae* are devoid of costal processes.

The sternum.—The ventral ends of the ribs become united to one another by a longitudinal bar termed the *sternal plate*, and opposite the first seven pairs of ribs these sternal plates fuse in the middle line to form the manubrium and body of the sternum. The xiphoid process is formed by a backward extension of the sternal plates.

The skull.—The bones of the cranium are developed from the mesoderm which invests the cerebral vesicles. At the end of the first and beginning of the second month of foetal life this mesoderm begins to thicken and form masses of blastema. These blastemal masses represent the earliest distinguishable elements of the skeleton of the head, and first become evident in the occipital region where they

form a plate, the so-called *occipital plate*; in the middle of this plate the notochord runs sagittally. The occipital plate sends out on either side two processes which surround the hypoglossal nerve and form the hypoglossal canal.

The occipital plate is continued forwards as a thin blastemal layer on the dorsal aspect of the pharynx and reaches the rudiment of the hypophysis. At the beginning of the second month it surrounds the duct of the hypophysis and extends between the nasal fossæ where it forms the basis of the ethmoid and the nasal septum.

About the fifth week the two auditory vesicles become enclosed in blastemal capsules, each of which is soon differentiated into a dorsolateral part enveloping the semicircular canals and a ventromedial part surrounding the cochlea; at the upper boundary between these two parts the facial nerve lies in a deep groove. The blastemal auditory capsules fuse with the lateral processes of the occipital plate, leaving, however, a wide gap between each capsule and the more median part of the occipital plate; through this gap the internal jugular vein, and the glossopharyngeal, vagus and accessory cerebral nerves are transmitted.

At this stage the blastema which surrounds the hypophysial duct and forms the rudiment of the post-sphenoidal part of the body of the sphenoidal bone, sends

FIG. 108.—Sagittal section of the cephalic end of the notochord. (Keibel.)

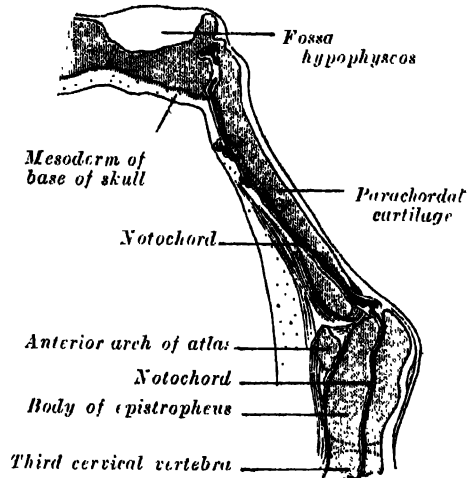
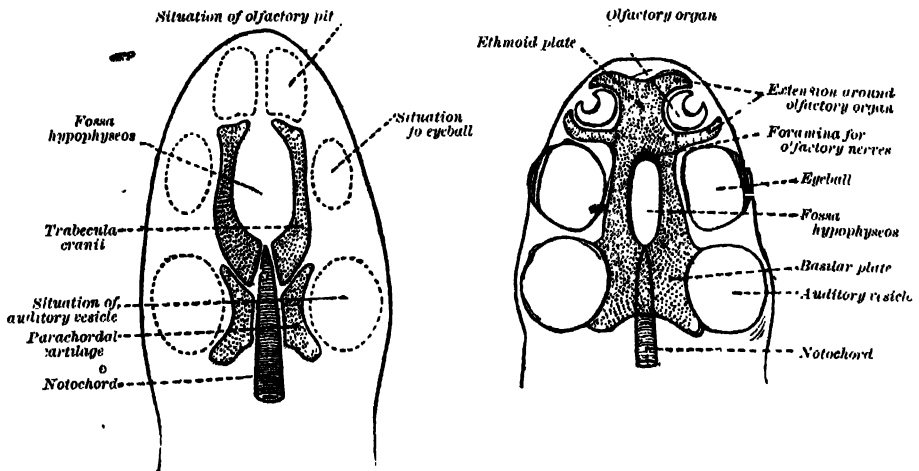


FIG. 109.—Diagrams of the cartilaginous cranium. (Wiedersheim.)

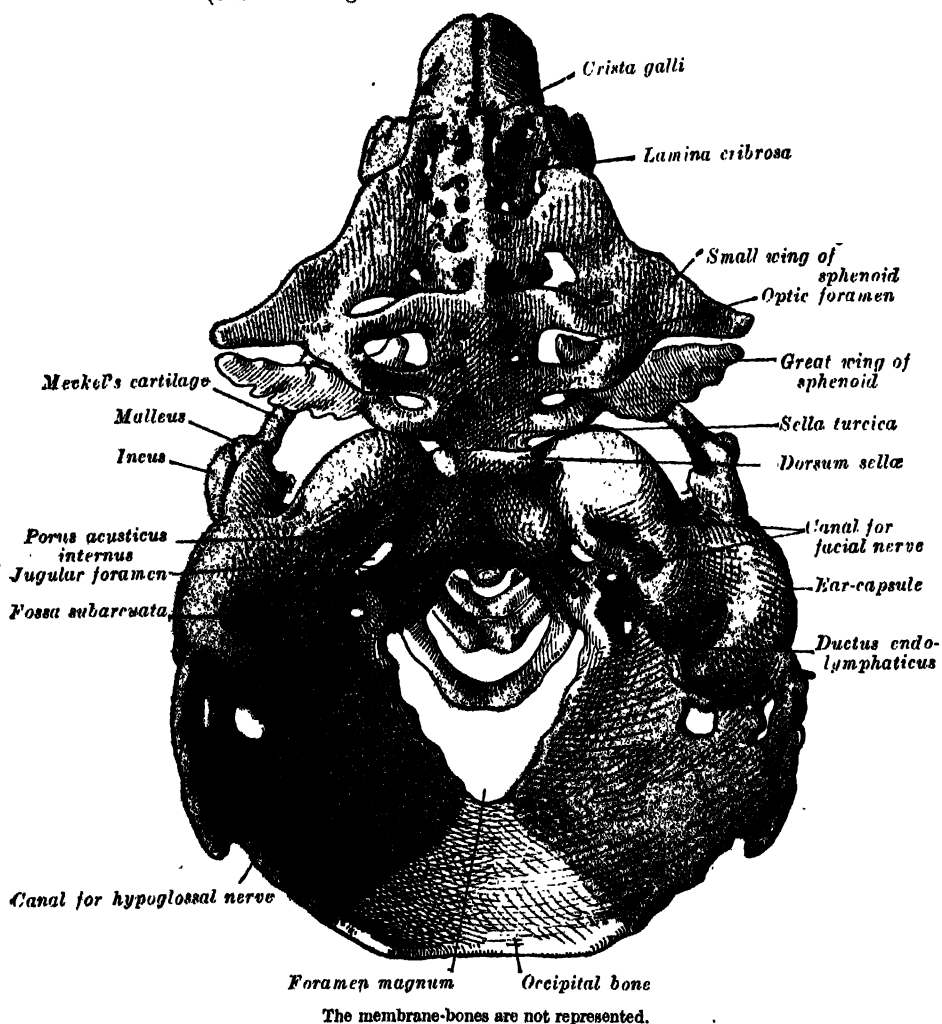


out a wing-like process on either side, the future great wing (*ala magna*) of the sphenoidal bone. More anteriorly, from the central blastema which is to form the interorbitonasal septum, processes extend laterally and indicate the sites of the small wings (*alæ parvæ*) of the sphenoidal bone, while condensations occur on either side of the nasal fossæ and blend above with the blastemal septum.

The first indications of the vault of the skull are seen about the thirtieth day, and consist of blastemal plates which appear at the sides of the head and gradually extend into the upper wall where they blend with one another; they also blend with the blastema at the base of the cranium.

In the shark and dogfish this blastemal cranium undergoes complete chondrification and forms the cartilaginous skull or chondrocranium of these animals. In mammals the process of chondrification is limited to the base of the skull, including a narrow region dorsal to the foramen magnum. Chondrification takes place primarily in two regions: (a) the posterior or *chordal* part of the base of the skull is developed from the blastema which surrounds the notochord, and exhibits traces of four primitive segments separated from one another by the roots of the hypo-

FIG. 110.—Drawing of a model of the chondrocranium of a human embryo 8 cm. long.
(From Hertwig's *Handbuch der Entwicklungslehre*.)



glossal nerve; (b) the anterior or *prechordal* part is developed in front of the notochord and shows no regular division into primitive segments.

In the lower animals a pair of cartilages appears in each part, viz. a pair of *parachordal cartilages*, one on either side of the notochord, and a pair of *prechordal cartilages* or *trabeculae cranii*, in front of the notochord (fig. 109). These structures are represented in man by paired nuclei of chondrification in the chordal and prechordal parts respectively.

* Chondrification of the skull begins in the second month of foetal life, even

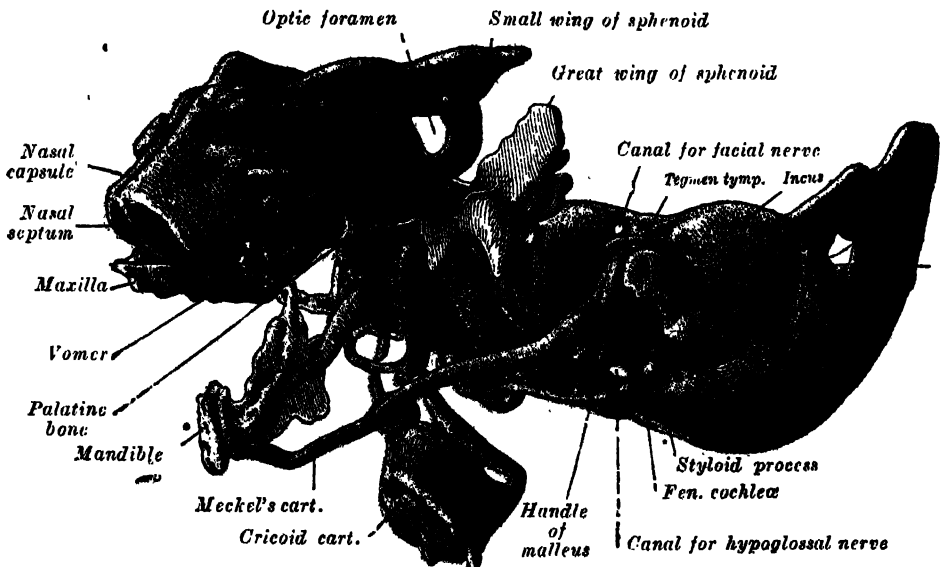
* The following description is mainly based on the extensive researches of E. Fawcett. The reader is referred for further details to the *Journal of Anatomy and Physiology*, volumes xlv. and xlvi., and to the *Proceedings of the Anatomical Society of Great Britain and Ireland* for the year 1918.

before the blastemal stage is completed, and the first nuclei appear in the occipital plate, one on either side of the notochord, medial to the hypoglossal canal. About the thirty-sixth day these two nuclei fuse anteriorly on the dorsal surface of the notochord, and later they fuse posteriorly on its ventral surface. Thus the notochord lies dorsal to the caudal part of the cartilaginous occipital plate, then traverses the plate and lies ventral to it, and finally passes in front of it and ends on the dorsal surface of the post-sphenoidal cartilage (fig. 108).

The posterior part of the sphenoidal cartilage chondrifies from two centres (*trabeculae cranii*) one on either side of the developing hypophysis; these unite first behind and then in front of the duct of the hypophysis, and in this way the craniopharyngeal canal, through which the hypophyseal diverticulum ascends into the skull, is formed; this canal is usually obliterated at the third month, but may remain open.

The central blastema, in front of the hypophysis probably undergoes independent chondrification; it speedily joins with the posterior end of the chondrifying inter-

FIG. 111.—The same model as shown in fig. 110, from the left side.



Certain of the membrane-bones are represented in yellow.

orbitonasal septum, and from these are subsequently developed the presphenoidal part of the sphenoidal bone and the bony (ethmoidal) part of the nasal septum. All the above-mentioned parts ultimately fuse and form a continuous cartilaginous stem from the anterior edge of the foramen magnum to the anterior end of the nose.

The blastemal auditory capsule next undergoes chondrification, the portion surrounding the semicircular canals chondrifying before that enveloping the cochlea. From the cartilaginous occipital plate, lateral to the hypoglossal canal, a cartilaginous bar extends on either side; these two bars pass partly under the canalicular part of the capsule, then dorsally over the brain, and ultimately meet in the mid-dorsal line to form the *tectum posterius*, which is afterwards ossified to form the lower part of the squama occipitalis. In front of this a narrow strip of cartilage, the *tectum anterius*, is developed, but later disappears.

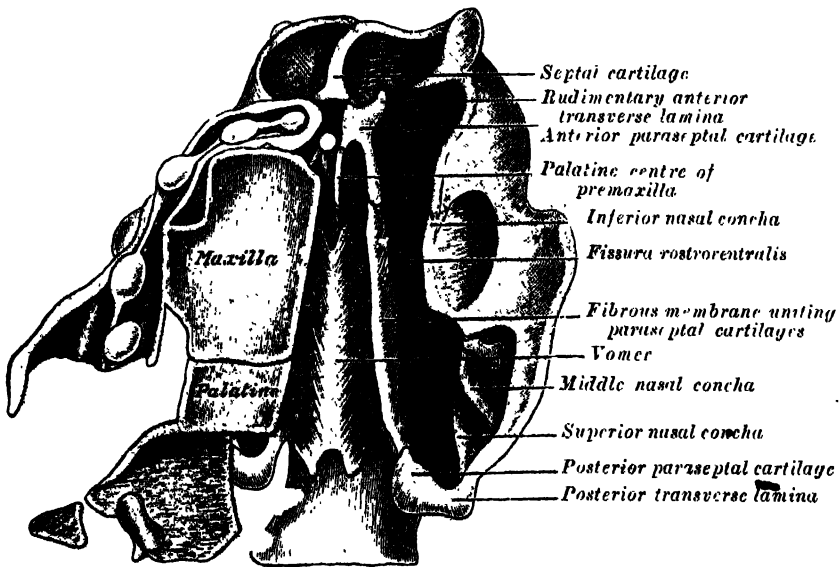
The great wings of the sphenoidal bone have separate cartilaginous nuclei; these fuse with the post-sphenoidal cartilage and with two nuclei which connect the post-sphenoidal cartilage and the corresponding great wing with the anterior end of the cochlear capsule, lateral to the carotid artery. These nuclei form, on either side, the alar process which later ossifies as the lingula. The cartilaginous great wing is smaller than the small wing and only gives rise to the root of the pterygoid process and to that part of the bone which surrounds the maxillary division of the trigeminal nerve.

Between the great wing and the auditory capsule is a wide space which lodges the semilunar (Gasserian) ganglion and transmits the mandibular division of the trigeminal nerve and the middle meningeal artery. The backward growth of the alar process cuts off this space from the carotid canal, and at a later date the mandibular nerve and middle meningeal artery are surrounded by membrane bone. The space between the great and small wings forms the superior orbital (sphenoidal) fissure.

Chondrification of the small wing commences lateral to the optic nerve, and from this centre ingrowths extend in front of and behind the optic nerve and fuse with hinder part of the interorbitonasal septum and so form the optic foramen. Ossification of the small wing begins just lateral to the optic foramen, but does not extend very far out; a considerable part of the cartilage disappears, and owing to this, the small wing, in the bony condition, is much smaller than the great wing.

The nasal capsule is situated in front of the small wings, and is well developed by the third month; it consists of a central part, or septum, and two lateral parts.

FIG. 112.—Ventral view of left half of nasal capsule of a 65 mm. human embryo. (Fawcett.)



The septum lies partly under the brain (subcerebral) and partly in front of the brain (precerebral); its lower margin is almost horizontal and is, for a time, free; its anterior border intervenes between the anterior nares (fenestræ narinae).

The lateral parts of the capsule are primarily suspended from the precerebral part of the septum; later they are connected with the subcerebral part of the septum by the lamina cribrosa of the ethmoidal bone. Each lateral part consists of an anterior, an intermediate and a posterior portion. The anterior and intermediate portions are separated externally by an anterolateral sulcus which corresponds internally with a semilunar crest; the lower end of this crest forms the uncinat process of the ethmoidal bone. The posterior and intermediate portions are separated by a faint postero-lateral sulcus which corresponds internally with the middle nasal concha. The lower edge of the lateral wall of the capsule is incurved to form the inferior nasal concha which, at the fifth month, becomes ossified and detached from the lateral wall of the capsule.

In man the floor of the nasal capsule is very incomplete. In rodents and some marsupials it consists of an anterior and a posterior transverse lamina connecting the lateral wall of the capsule with the septum; in front of the anterior lamina is the fenestra narina. The anterior and posterior transverse laminae are connected by a bar of cartilage which runs backwards alongside the septum and forms the common paranasal cartilage; the anterior part of this cartilage is bilaminar, and between the laminae the organ of Jacobson is lodged; the posterior part is small and cylindrical.

In man the greater part of the anterior transverse lamina has disappeared and thus the fenestra narina is continuous with the fenestra basalis, the two forming the fissura rostroventralis; the medial segment only of the anterior transverse lamina remains as the processus lateralis ventralis. Further, only the anterior and posterior segments of the common paraseptal cartilage are developed in man; these parts are termed the anterior and posterior paraseptal cartilages and are united to one another by fibrous membrane.

Part of the cartilaginous capsule is ossified to form the ethmoidal bone and the inferior nasal concha, part remains cartilaginous as the septal and alar cartilages of the nose, and part is replaced by membrane bones.

The ventral surface of the chondrocranium is indirectly connected with the cartilages of the visceral arches, the fate of which is described below.

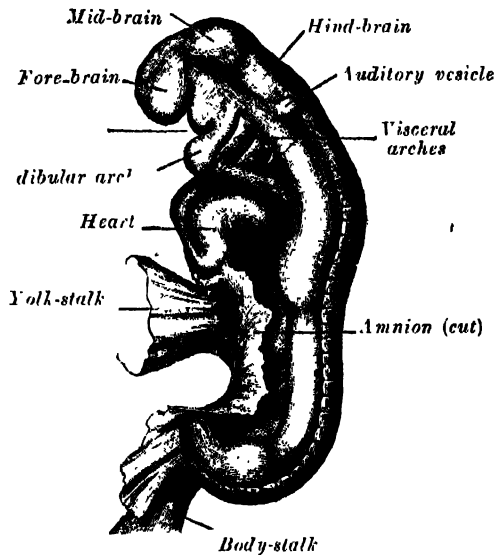
The bones of the vault of the skull are of membranous formation, and are termed *dermal* or *covering bones*. They comprise the upper part of the squama occipitalis (interparietal), the squamæ and tympanic parts of the temporals, the parietals, the frontal. Some of them remain distinct throughout life (e.g. parietal and frontal), while others join with the bones of the chondrocranium (e.g. interparietal and squamæ of temporals).

The branchial or visceral arches and pharyngeal pouches.—In the lateral walls of the anterior part of the fore-gut five *pharyngeal pouches* appear (fig. 115); each of the upper four pouches is prolonged into a dorsal and a ventral diverticulum. Over these pouches corresponding indentations of the ectoderm occur, forming what are known as the *branchial* or *outer pharyngeal grooves*. The mesoderm which intervenes between the pharyngeal pouches and the outer pharyngeal grooves is pressed aside and the ectoderm unites with the entoderm of the fore-gut along the floors of the grooves to form thin *closing membranes* between the fore-gut and the exterior. Later the mesoderm again penetrates between the entoderm and the ectoderm. In gill-bearing animals the closing membranes disappear, and the grooves become the gill-clefts which open from the pharynx on to the exterior; perforation, however, does not occur in birds or mammals.

The pharyngeal grooves separate a series of rounded bars or arches, the *branchial* or *visceral arches* in which thickening and consolidation of the mesoderm take place (figs. 113 to 115). The dorsal ends of these arches are attached to the sides of the head, while the ventral extremities ultimately meet in the middle line of the neck. In all, six arches make their appearance, but of these only the first four are visible externally. The first arch is named the *mandibular*, and the second the *hyoid*; the others have no distinctive names. In each arch the central part of the mesoderm consolidates and is then converted into a cartilaginous bar, consisting of right and left halves. Moreover, each arch is traversed by a nerve and by one of the primitive aortic arches.

The *mandibular arch* lies between the stomodæum or primitive mouth and the first branchial-groove: from it are developed the lower lip, the mandible, the muscles of mastication, and the anterior part of the tongue. Its cartilaginous bar is formed by what are known as *Meckel's cartilages* (right and left) (fig. 116). The dorsal ends of these cartilages are ossified to form two of the three bones of the middle ear, viz. the malleus and incus; the ventral ends meet each other in the region of the

FIG. 113.—Embryo between eighteen and twenty-one days. (Hiss.)



symphysis menti, and are usually regarded as undergoing ossification to form that portion of the mandible which contains the incisor teeth. The intervening part of the cartilage disappears; the portion immediately adjacent to the malleus and incus is replaced by fibrous membrane which constitutes the sphenomandibular ligament, while from the connective tissue covering the remainder of the cartilage

FIG. 114.—Head end of a human embryo, about the end of the fourth week. (From model by Peter.)



the greater part of the mandible is ossified. From the dorsal ends of the mandibular arch a triangular process, the *maxillary process*, grows forwards on either side and forms the cheek and lateral part of the upper lip.

The second or *hyoid arch* assists in forming the side and front of the neck. From its dorsal median portion the third bone of the middle ear, viz. the stapes, is developed, and subsequently becomes attached to the auditory capsule. From the ventral part of the arch the styloid process, stylohyoid ligament, and lesser cornu of the hyoid bone are developed: the glossopalatine arch indicates the position of the hyoid arch. The cartilage of the *third arch* gives origin to the greater cornu of the hyoid bone. The ventral ends of the second and third arches unite with those of the opposite side, and form a transverse band, from which the body of the hyoid bone and the posterior part of the tongue are developed. The

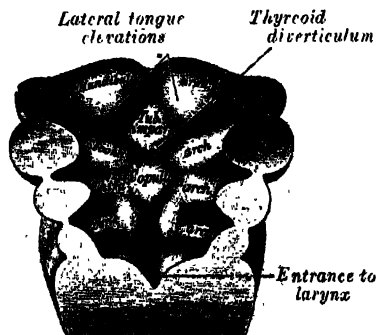
ventral portions of the cartilages of the *fourth* and *fifth* arches unite to form the thyroid cartilage; from the cartilages of the *sixth arch* the cricoid and arytenoid cartilages and the cartilages of the trachea are developed.*

The mandibular and hyoid arches grow more rapidly than those behind them, with the result that the third and fourth arches recede from the surface and form the floor of a deep depression, the *sinus cervicalis*. The hyoid arch grows backwards and overlaps the sinus, the opening from which assumes the form of a narrow duct; this duct closes and converts the sinus into a vesicle which disappears at an early period of development.

From the first branchial groove the concha and the external acoustic meatus are developed, while around the groove there appear, on the mandibular and hyoid arches, a number of swellings from which the auricula or pinna is formed. From the upper or dorsal parts of the first and second pharyngeal pouches the auditory tube and the tympanic cavity are developed (page 107; the closing membrane between the mandibular and hyoid arches is invaded by mesoderm, and forms the tympanic membrane. No traces of the second, third, or fourth branchial grooves persist. The dorsal

angle of the second pharyngeal pouch is named the *sinus tonsillaris*; in it the tonsil is developed, and above the tonsil a trace of the sinus persists as the suprtonsillar

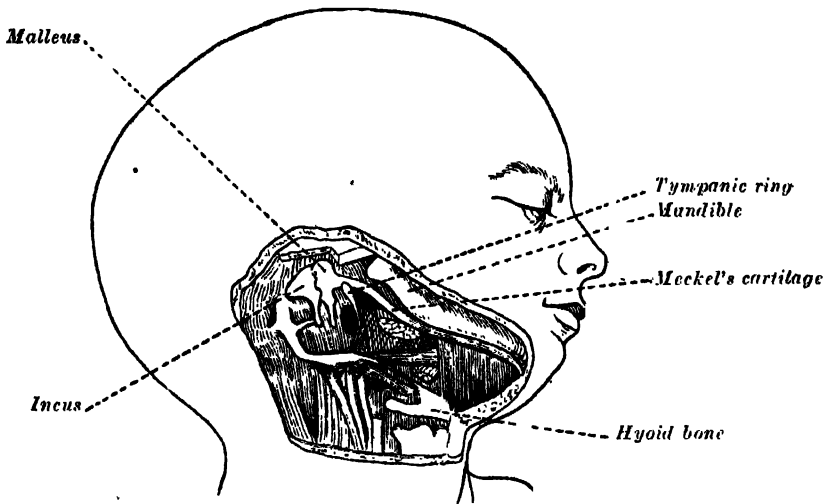
FIG. 115.—Floor of pharynx of embryo shown in fig. 114.



* Fawcett (*Proceedings of the Anatomical Society of Great Britain and Ireland*, 1916) is of opinion that the thyroid cartilage is formed from the fourth arch, and the cricoid cartilage from the fifth arch.

fossa. The lateral recess of the pharynx, or fossa of Rosenmüller, is by some regarded as a persistent part of the second pharyngeal pouch, but it is probably developed as a secondary formation. From the third pharyngeal pouch the thymus arises as an entodermal diverticulum on either side, and from the fourth pouches

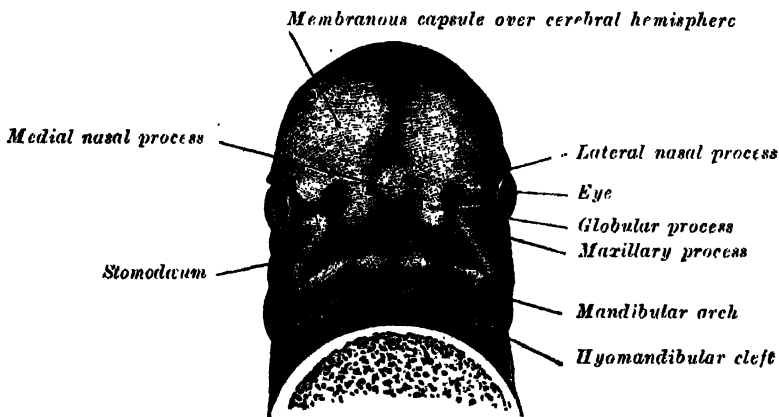
FIG. 116.—Head and neck of a human embryo eighteen weeks old, with Meckel's cartilage and hyoid bar exposed. (After Kölliker.)



small diverticula project and become incorporated with the thymus, but in man they probably never form true thymus tissue. The parathyroids arise as diverticula from the third and fourth pouches. From the fifth pouches the ultimobranchial bodies originate and are enveloped by the lateral prolongations of the median thyroid rudiment; they do not, however, form true thyroid tissue, nor are any traces of them found in the human adult.

The nose and face.—During the third week two areas of thickened ectoderm, the *olfactory areas*, appear immediately under the fore-brain in the anterior wall of

FIG. 117.—Under surface of the head of a human embryo about twenty-nine days old. (After His.)



the stomodæum, one on either side of a region termed the *frontonasal process*. By the upgrowth of the surrounding parts these areas are converted into the *olfactory pits*, which indent the frontonasal process and divide it into a *medial* and two *lateral nasal processes* (figs. 117, 118). The rounded lateral angles of the medial

process are named the *globular processes* (His). The olfactory pits form the rudiments of the nasal cavities, and from their ectodermal lining the epithelium of the nasal cavities is derived, with the exception of that of the inferior meatuses which are formed from the stomodæum. The mesodermal plates represented on the surface by the globular processes are termed the *nasal laminæ*; these laminæ are at first some distance apart, but, gradually approaching, they ultimately fuse and form the nasal septum; the processes themselves meet in the middle line, and form the premaxillæ and the central part of the upper lip (fig. 121). The depressed part of the medial nasal process between the globular processes forms the lower part of the nasal septum or *columella*; while above this is seen a prominent angle, which becomes the future apex (fig. 118), and still higher a flat area, the future bridge of the nose. The lateral nasal processes form the alæ of the nose.

Continuous with the dorsal end of the mandibular arch, and growing forwards from its cephalic border, is a triangular process—the *maxillary process*—the ventral extremity of which is separated from the mandibular arch by a >-shaped notch

FIG. 118.—Head-end of a human embryo of about thirty to thirty-one days. (From model by Peter.)

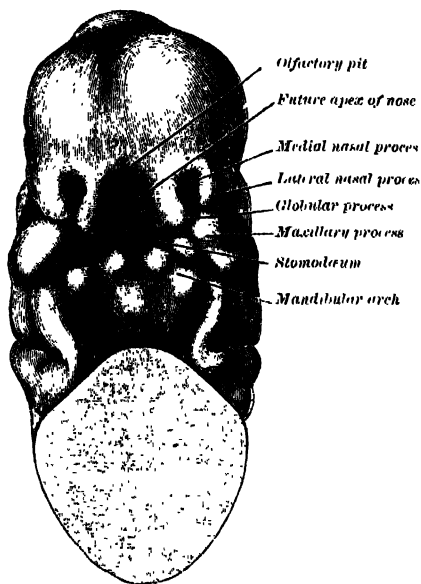
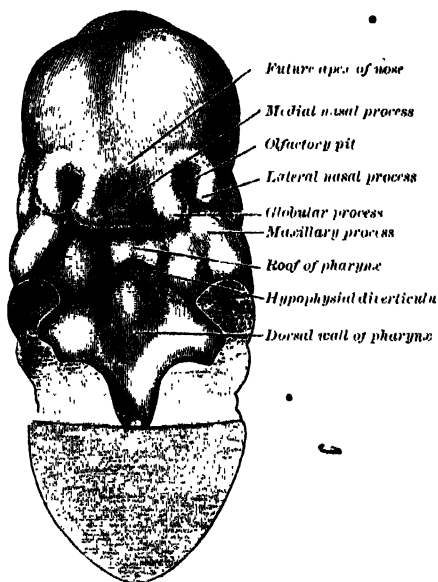


FIG. 119.—Same embryo as shown in fig. 118, with the front wall of the pharynx removed.



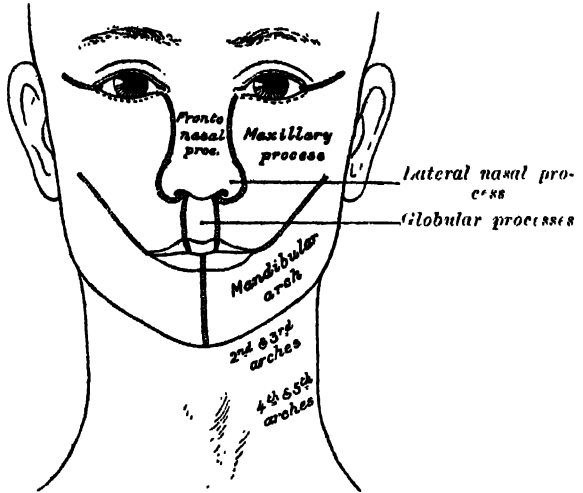
(fig. 117). The maxillary process forms the lateral wall and floor of the orbit, and in it are ossified the zygomatic and palatine bones and the greater part of the maxilla; it meets with the lateral nasal process, from which, however, it is separated for a time by a groove, the *naso-optic furrow*, extending from the furrow encircling the eyeball to the olfactory pit. The maxillary processes ultimately fuse with the lateral nasal and globular processes, and form the lateral parts of the upper lip and the posterior boundaries of the nares (figs. 120, 121). From the third to the fifth month the nares are filled by masses of epithelium, on the breaking down and disappearance of which the permanent openings are produced. By the fusion of the maxillary processes with the nasal and globular processes in the roof of the stomodæum the *primitive palate* (fig. 122) is formed, and the olfactory pits extend backwards above it. The posterior end of each pit is closed by an epithelial membrane, the *bucco-nasal membrane*, formed by the apposition of the nasal and stomodæal epithelium. About the fifth week the bucconasal membranes rupture and the *primitive choanæ* or openings between the olfactory pits and the stomodæum are established. The floor of the nasal cavity is completed by the development of a pair of shelf-like *palatine processes* which appear about the sixth week and extend medialwards from the maxillary processes (figs. 123, 124); these coalesce with each other and with the nasal septum in the middle line, and constitute the entire hard plate, except a small part in front which is formed by the premaxillæ (page 229). The soft palate is

formed by two secondary backward growths, one on either side, from the palatine processes; into these the palatine muscles extend, and the two parts ultimately join to form the soft palate and uvula. Two apertures persist for a time between the palatine processes and the premaxillæ, and represent the permanent channels

FIG. 120.—Head of a human embryo of about eight weeks, in which the nose and mouth are formed. (His.)

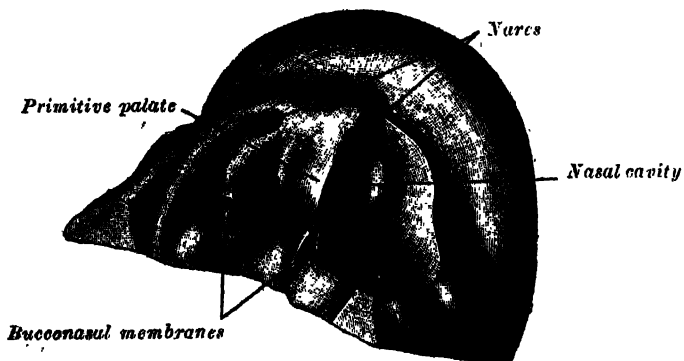


FIG. 121.—Diagram showing the regions of the adult face and neck related to the frontonasal and maxillary processes and the branchial arches.



which in the lower animals connect the nose and mouth. The union of the parts which form the palate commences in front, the premaxillary and palatine processes joining in the eighth week, while the region of the future hard palate is completed by the ninth, and that of the soft palate by the eleventh week. By the completion of the palate the *permanent choanæ* are formed and are situated a considerable distance behind the primitive choanæ. The deformity known as cleft palate results from a non-union of the palatine processes, and that of hare-lip from a non-union of the maxillary and globular processes (see page 264). The nasal cavity is divided

FIG. 122.—Primitive palate of a human embryo of thirty-seven to thirty-eight days. (From model by Peter.)



On the left side the lateral wall of the nasal cavity has been removed.

by a cartilaginous septum, the anterior part of which persists as the septal cartilage of the nose, but the posterior and upper parts are replaced by the vomer and lamina perpendicularis of the ethmoid. On either side of the nasal septum, at its lower and anterior part, the ectoderm is invaginated to form a blind pouch or diverticulum which extends backwards and upwards into the nasal septum and is supported by

a curved plate of cartilage. These pouches form the rudiments of the *vomer* and *nasal organs* of Jacobson, which open below, close to the junction of the premaxillary and maxillary bones.*

FIG. 123.—The roof of the mouth of a human embryo about two and a half months old, showing the mode of formation of the palate. (His.)

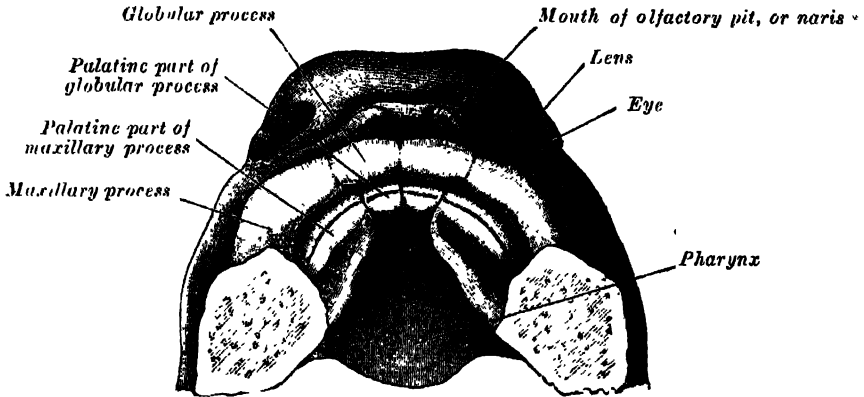
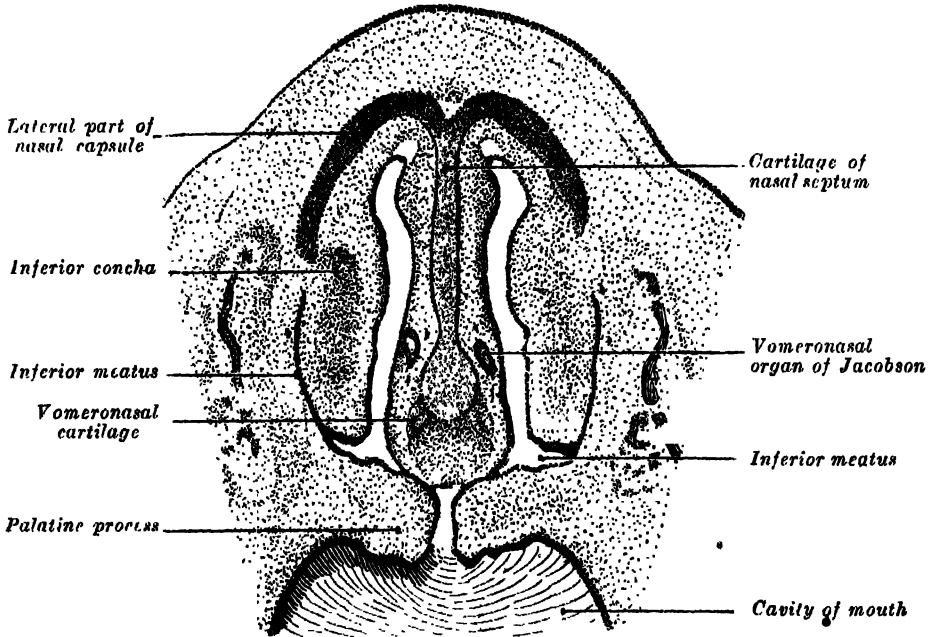


FIG. 124.—Frontal section of nasal cavities of a human embryo 28 mm. long. (Kollmann.)



The limbs.—In the third week the limbs begin to make their appearance as small elevations or buds at the side of the trunk (fig. 125). Prolongations from several primitive segments extend into each bud, and carry with them the anterior divisions of the corresponding spinal nerves; the nerves supplying the limbs indicate the number of primitive segments which contribute to their formation—the upper limb being derived from seven, viz. fourth cervical to second thoracic inclusive,

* J. Ernest Frazer (Hunterian Lecture, *Lancet*, July 8, 1916) maintains that the increase in size of the nasal cavities takes place in an upward and backward direction, and the septum is simply the part of the roof left undisturbed between the paired upgrowths. He also points out that by the ninth week the primitive choanae extend from the primitive palate to the top of the cavity of the mouth, and when the palatal folds meet they fuse with the lower two-thirds or three-fourths of the septum, while the upper one-fourth or so of the septum remains between the upper parts of the openings which constitute the permanent choanae.

and the lower limb from ten, viz. twelfth thoracic to fourth sacral inclusive. The axial part of the mesoderm of the limb-bud condenses and is converted into its cartilaginous skeleton, and by the ossification of this the bones of the limbs are formed. The limbs are at first directed backwards nearly parallel to the long axis of the trunk; by the sixth week their long axes are at right angles to that of the trunk, and the three chief divisions of each limb are marked off by furrows—arm, forearm, and hand in the upper limb; thigh, leg, and foot in the lower (fig. 126). The future *flexor* surface of the limb is directed ventrally; the *extensor* surface, dorsally; one border, the *pre-axial*, looks towards the cephalic end of the embryo, and the other, the *post-axial*, towards the caudal end. The lateral epicondyle of the humerus, the radius, and the thumb lie along the pre-axial border of the upper limb; the medial epicondyle of the femur, the tibia, and the great toe along the corresponding border of the lower limb. The limbs next undergo a rotation or torsion through an angle of 90° around their long axes, the rotation being effected almost entirely at the limb girdles. The rotation of the upper limb is outwards and forwards; that of the lower limb is inwards and backwards. As a consequence of this rotation the pre-axial (radial) border of the fore-limb is directed lateralwards, and the pre-axial (tibial) border of the hind-limb medialwards; thus the flexor surface of the fore-limb is turned forwards, and that of the hind-limb backwards.

FIG. 126.—Embryo of about six weeks. (Hiss.)

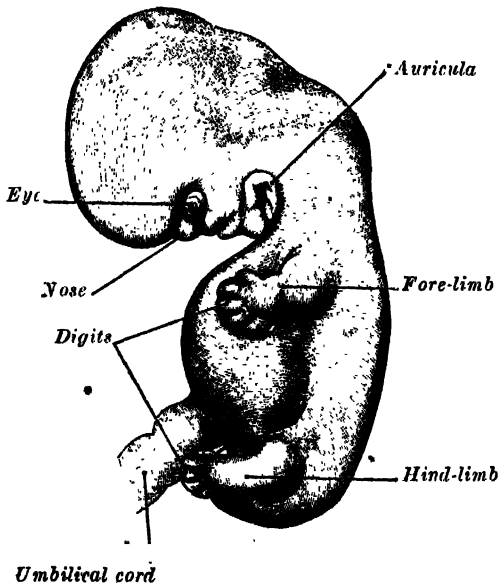
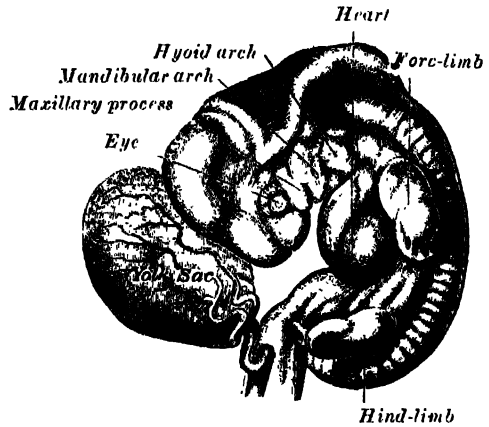


FIG. 125.—Human embryo from thirty-one to thirty-four days. (Hiss.)



The pre-axial part is derived from the anterior primitive segments, the post-axial from the posterior primitive segments of the limb-bud; and this explains, to a large extent, the innervation of the adult limb, the nerves of the more anterior segments being distributed along the pre-axial (radial or tibial), and those of the more posterior segments along the post-axial (ulnar or fibular) border of the limb.

The joints.—The mesoderm from which the different parts of the skeleton are formed at first shows no differentiation into masses corresponding with the individual bones; thus, continuous cores of mesoderm form the axes of the limb-buds and a continuous column of mesoderm the future vertebral column. The first indications of the differentiation of the bones and

joints are circumscribed condensations of the mesoderm; these condensed parts become chondrified and finally ossified to form the bones of the skeleton. The intervening non-condensed portions consist at first of undifferentiated mesoderm, which may be converted into fibrous tissue as in the case of the skull bones, a synarthrodial joint being the result; or it may become partly cartilaginous, in which case an amphiarthrodial joint is formed; or it may become

looser in texture, a cavity ultimately appearing in its midst, while the cells lining the sides of this cavity form a synovial stratum, and thus a diarthrodial joint is developed; in some diarthrodial joints portions of the mesoderm persist and form articular discs.

The tissue surrounding the original mesodermal core forms fibrous sheaths for the developing bones (perichondrium and periosteum) which are continued between the ends of the bones over the synovial strata as the fibrous capsules of the joints. These capsules are not of uniform thickness, so that in them may be recognised specially strengthened bands which are described as ligaments. This, however, is not the only method of formation of ligaments. In some cases by modification of, or derivations from, the tendons surrounding the joint, additional ligamentous bands are provided to strengthen the articulations.

The muscles.—The voluntary muscles are developed from the myotomes of the primitive segments. Portions of the myotomes retain their position on the sides of the neural tube, where they may remain distinct from each other and form the short muscles of the vertebral column, or fuse with corresponding portions of neighbouring myotomes to form the Sacrospinales and their continuations. Other portions of the myotomes extend into the trunk wall where again they may retain their segmental condition, as in the Intercostales, or may fuse with adjacent segments to form the flat muscles of the abdominal wall. Finally, portions of the myotomes wander into the limb-buds and there undergo fusions and alterations in form to produce the limb muscles. The original segmental character of the limb muscles is therefore lost, but their segmental nerve supplies are retained. Some of the limb muscles expand and migrate secondarily towards the mid-dorsal line (e.g. Trapezius and Latissimus dorsi) or towards the mid-ventral line (e.g. Pectoralis major). Again, muscles may migrate in a cephalic direction (e.g. the facial muscles which are derived from the hyoid arch), or in a caudal direction (e.g. the Serratus anterior). In all cases they carry with them the segmental nerves of the myotomes from which they are derived; one example of this will suffice, viz. the Serratus anterior, which is derived from the fifth, sixth, and seventh cervical segments as is indicated by its nerves of supply. In man and the higher vertebrates many of the derivatives of the myotomes degenerate and are converted into aponeuroses (e.g. galea aponeurotica, and the aponeuroses of the abdominal muscles) or ligaments (e.g. the sacrotuberous ligament and the fibular collateral ligament of the knee).

The involuntary muscles are derived from the splanchnopleure mesoderm.

The skin and its appendages.—The epidermis, hairs, nails, sebaceous and sudoriferous glands are developed from the ectoderm, the corium or true skin from the mesoderm. The ectoderm at first consists of a single stratum of cells, but by the fifth week two strata can be recognised, a superficial, named the *epitrichium*, consisting of flat cells, the nuclei of which stain readily, and a deep, named the *stratum germinativum*, consisting at first of cubical, but later of columnar, cells. By multiplication and differentiation of the cells of the stratum germinativum the different layers of the epidermis are developed. Towards the end of the third month the mesoderm condenses to form the corium, and at about the same time the subcutaneous areolar tissue is differentiated; in the fourth month the dermal papillæ begin to make their appearance. A considerable desquamation of the epidermis takes place, and this desquamated epidermis, mixed with sebaceous secretion, constitutes the *vernix caseosa*, with which the skin is smeared during the last three months of foetal life.

The *hairs* (fig. 127) originate as thickenings of the epidermis which grow obliquely downwards as solid buds into the corium, each bud consisting of an outer stratum of columnar cells and a core of polygonal cells. The deep end of each bud expands to form the hair-bulb which is moulded over a papilla of condensed mesoderm. The cells of the hair-bulb proliferate and form a cone of cells, from which the scapus or shaft of the hair and its inner sheath are developed. The hairs gradually lengthen by growth at the hair-bulb, and when they project on the surface they push before them the *epitrichium* which is broken up and shed.

The *sebaceous glands* originate as lateral outgrowths from the sides of the hair-buds, and, pushing their way into the mesoderm, divide into three or four oval or flask-shaped alveoli.

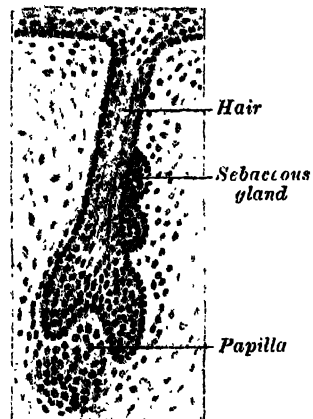
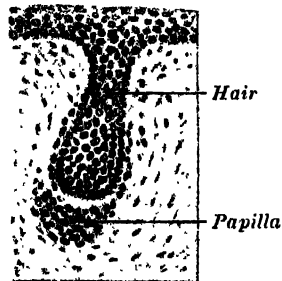
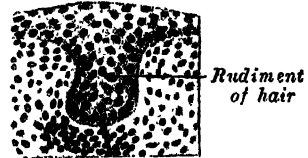
The rudiments of the *sudoriferous* or *sweat glands* make their appearance on the palms of the hands and soles of the feet in the fourth month, and closely resemble the rudiments of the hairs, each beginning as a solid downgrowth of the ectoderm.

The ectodermal downgrowth lengthens, and its deeper part coils on itself and forms the body of the gland. A lumen is developed in the downgrowth about the seventh month of foetal life, and opens on the surface by a duct which is lined by two layers of cells. In the secreting part of the gland the outer layer of cells is modified to form a stratum of smooth muscle-fibres which lies between the gland epithelium and the basement membrane. Many sudoriferous glands arise as ectodermal downgrowths from the superficial portions of the hair-follicles and later acquire independent openings on the surface of the skin.

The *mammary gland* may be looked upon as a collection of greatly modified sudoriferous glands; the epithelial lining of its ducts and alveoli is derived from the ectoderm, its supporting connective tissue from the mesoderm. On either side of the ventral surface of young embryos a thickened band of ectoderm, termed the *milk-ridge*, extends obliquely from the base of the fore-limb to the inguinal region near the middle line, and in some of the lower mammals (e.g. the sow) mammae are developed at intervals along this ridge. In man only one mamma, as a rule, is developed on either side of the middle line, but supernumerary glands or nipples are not infrequently found above or below the fully developed gland. The rudiment of the mamma appears as a thickening and subsequent downgrowth of the ectoderm; from this downgrowth between fifteen and twenty solid cords branch off, each cord representing a future lactiferous tubule and lobe of the gland. The deep ends of the cords subdivide in the mesoderm and form the gland alveoli. The region where the ectodermal thickening occurred is subsequently raised to form the nipple, and about the time of birth the tubules and alveoli become canalised. At the age of puberty, and in a greater degree towards the end of pregnancy, a marked enlargement of the gland, with the development of additional lobules and alveoli, takes place.

The rudiments of the *nails* can be seen in embryos of about 4.5 cm. in length, and appear as *primary nail-fields* of ectoderm on the dorsal surfaces of the terminal phalanges of the digits. At the proximal end and sides of each nail-field the epidermis is invaginated to form the nail-folds, while the opposite end, which will ultimately form the free end of the nail, is bounded by a shallow groove. The nail is developed from the posterior nail-fold and consists of modified stratum lucidum. The stratum corneum covers the nail and forms the *eponychium*; this disappears from the surface of the nail, with the exception of a narrow fold which overlaps the proximal part of the lunule of the nail.

FIG. 127.—Successive stages in the development of hair.



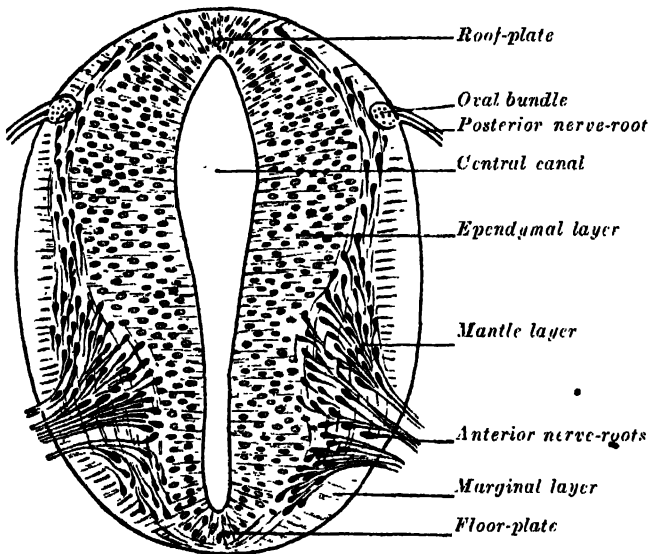
DEVELOPMENT OF THE NERVOUS SYSTEM AND SENSE-ORGANS

The nervous system is derived from the ectoderm and first appears as the neural groove on the dorsal aspect of the embryo (fig. 80). By the elevation and ultimate fusion of the neural folds, the groove is converted into the neural tube (fig. 82).

The anterior end of the tube expands to form the three primary brain-vesicles; the cavity of the tube is subsequently modified to form the ventricular cavities of the brain, and the central canal of the medulla spinalis; from the wall the nervous elements and the neuroglia of the brain and medulla spinalis are developed.

The medulla spinalis.—At first the wall of the neural tube is composed of a single layer of columnar ectodermal cells. The lateral parts of the wall soon thicken, while the dorsal and ventral parts remain thin, and are named the *roof- and floor-plates* (figs. 128, 130). A transverse section of the tube at this stage presents an oval outline and a slit-like lumen. The cells which constitute the wall of the tube proliferate rapidly, lose their cell-boundaries and form a syncytium consisting at first of dense protoplasm with closely packed nuclei, but later opening out and forming a loose meshwork with the cellular strands radiating from the central canal. Three layers of this syncytium may be defined—an internal or *ependymal*, an intermediate or *mantle*, and an external or *marginal* (fig. 128). The *ependymal layer* is ultimately converted into the *ependyma* of the central canal; the processes of its cells pass outwards towards the periphery of the medulla spinalis. The *marginal*

FIG. 128.—Transverse section of the medulla spinalis of a four weeks' embryo. (His.)

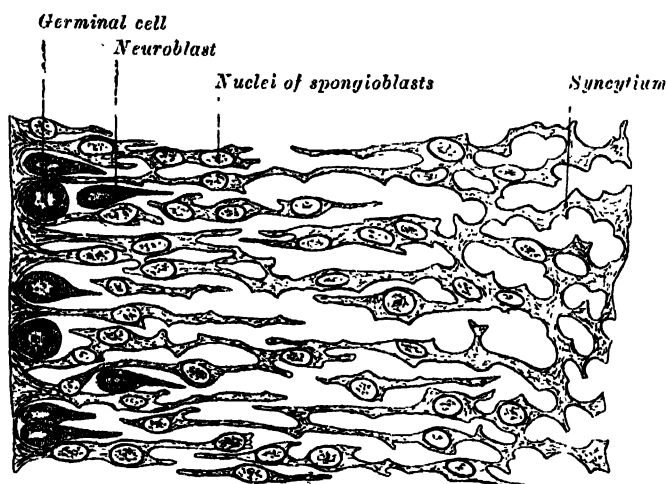


layer is devoid of nuclei, and later forms the supporting framework for the white funiculi of the medulla spinalis. The *mantle layer* represents the future grey columns of the medulla spinalis; in it the cells are differentiated into two sets, viz. (a) *spongioblasts* or young neuroglia-cells, and (b) *germinal cells*, which are the parents of the *neuroblasts* or young nerve-cells (fig. 129). The spongioblasts are at first connected to one another by filaments of the syncytium; in these, fibrils are developed, so that as the neuroglia cells become defined they exhibit their characteristic mature appearance with multiple processes proceeding from each cell. The germinal cells are large, round or oval, and first make their appearance between the ependymal cells on the sides of the central canal. They increase rapidly in number, so that by the fourth week they form an almost continuous layer on each side of the tube. No germinal cells are found in the roof- or floor-plates; the roof-plate retains, in certain regions of the brain, its epithelial character; elsewhere, its cells become spongioblasts. By subdivision the germinal cells give rise to the neuroblasts or young nerve-cells, which migrate outwards from the sides of the central canal into the mantle layer and neural crest, and at the same time become pear-shaped; the tapering part of the cell undergoes still further elongation, and forms the *axis-cylinder* of the cell.

The lateral walls of the medulla spinalis increase in thickness, and the central canal widens out near its dorsal extremity, and assumes a somewhat lozenge-shaped appearance. The widest part of the canal subdivides the lateral wall of the neural

tube into a *dorsal* or *alar*, and a *ventral* or *basal lamina* (fig. 130), a subdivision which extends forwards into the brain. The dorsal part of the canal is reduced to a mere slit which is subsequently obliterated by the approximation and fusion of its walls; the ventral part persists and forms the central canal of the adult medulla

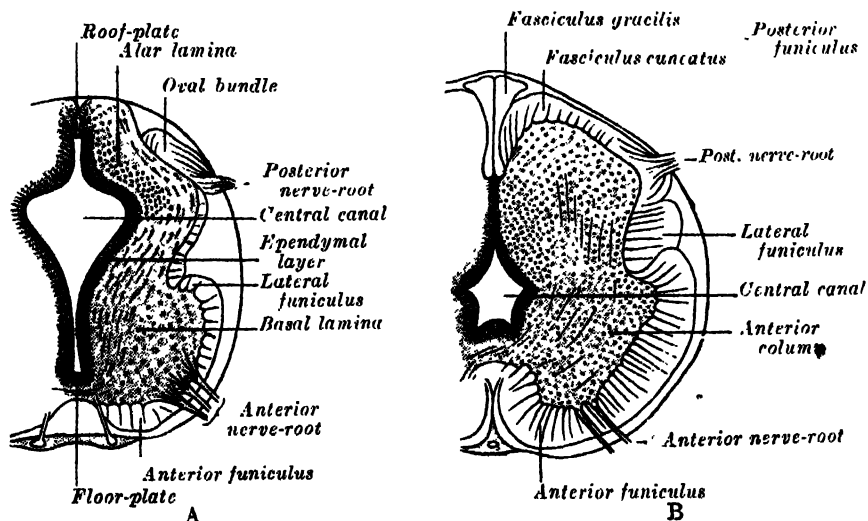
FIG. 129.—Transverse section of the medulla spinalis of a human embryo at the beginning of the fourth week. (After His.) The left edge of the figure corresponds to the lining of the central canal.



spinalis. The caudal end of the canal exhibits a conical expansion which is known as the *terminal ventricle*.

The ventral part of the mantle layer increases in thickness, and on cross-section appears as a triangular patch between the marginal and ependymal layers. This thickening is the rudiment of the anterior column of grey substance, and contains

FIG. 130.—Transverse sections of the medulla spinalis of human embryos. A, about four and a half weeks old. B, about three months old. (His.)



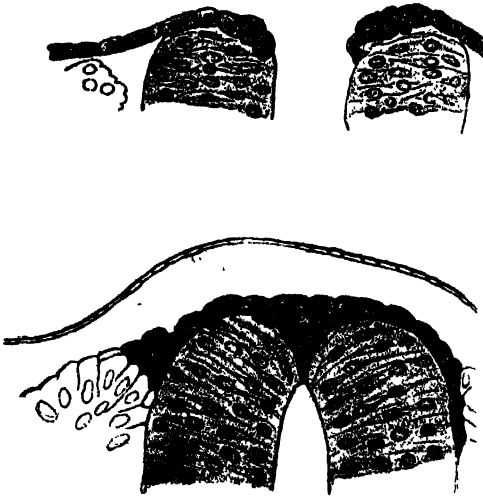
many neuroblasts, the axis-cylinders of which pass out through the marginal layer and form the anterior roots of the spinal nerves (figs. 128, 130). The thickening of the mantle layer gradually extends in a dorsal direction, and forms the posterior column of grey substance. The axons of many of the neuroblasts in the alar lamina run forward, cross in the floor-plate to the opposite side of the medulla spinalis, and form the rudiment of the anterior white commissure.

About the end of the fourth week nerve-fibres appear in the marginal layer. The first to develop are the short intersegmental fibres from the neuroblasts in the mantle zone, and the fibres of the posterior roots of the spinal nerves which grow into the medulla spinalis from the cells of the spinal ganglia. By the sixth week the fibres of the posterior roots of the spinal nerves form a well defined *oval bundle* in the peripheral part of the alar lamina; this bundle increases in size, and spreading towards the middle line forms the rudiment of the posterior funiculus. The long intersegmental fibres begin to appear about the third month, and the cerebrospinal fibres about the fifth month. All nerve-fibres are at first destitute of medullary sheaths, and different groups of fibres receive their sheaths at different times—the anterior and posterior nerve-roots are medullated about the fifth month, the cerebrospinal fibres after the ninth month.

By the growth of the anterior columns of grey substance, and by the increase in size of the anterior funiculi, an anterior furrow is formed between the lateral halves of the medulla spinalis; this gradually deepens to form the anterior median fissure (fig. 130, B). The mode of formation of the posterior septum is somewhat uncertain. Many believe that it is produced by the growing together of the walls of the posterior part of the central canal and by the development from its ependymal cells of a septum of fibrillated tissue which separates the future funiculi graciles.

Up to the third month of foetal life the medulla spinalis occupies the entire length of the vertebral canal, and the spinal nerves pass outwards at right angles.

FIG. 131.—Two stages in the development of the neural crest in the human embryo. (Lenhossék.)



From this time onwards, the vertebral column grows more rapidly than the medulla spinalis, and the latter, being fixed above through its continuity with the brain, gradually assumes a higher position within the vertebral canal. By the sixth month the lower end of the medulla spinalis reaches only as far as the base of the sacrum; at birth it is on a level with the third lumbar vertebra, and in the adult with the lower border of the first or upper border of the second lumbar vertebra. A delicate filament, the *filum terminale*, extends from the lower end of the medulla spinalis as far as the first segment of the coccyx.

The spinal nerves.—Each spinal nerve is attached to the medulla spinalis by an anterior and a posterior root.

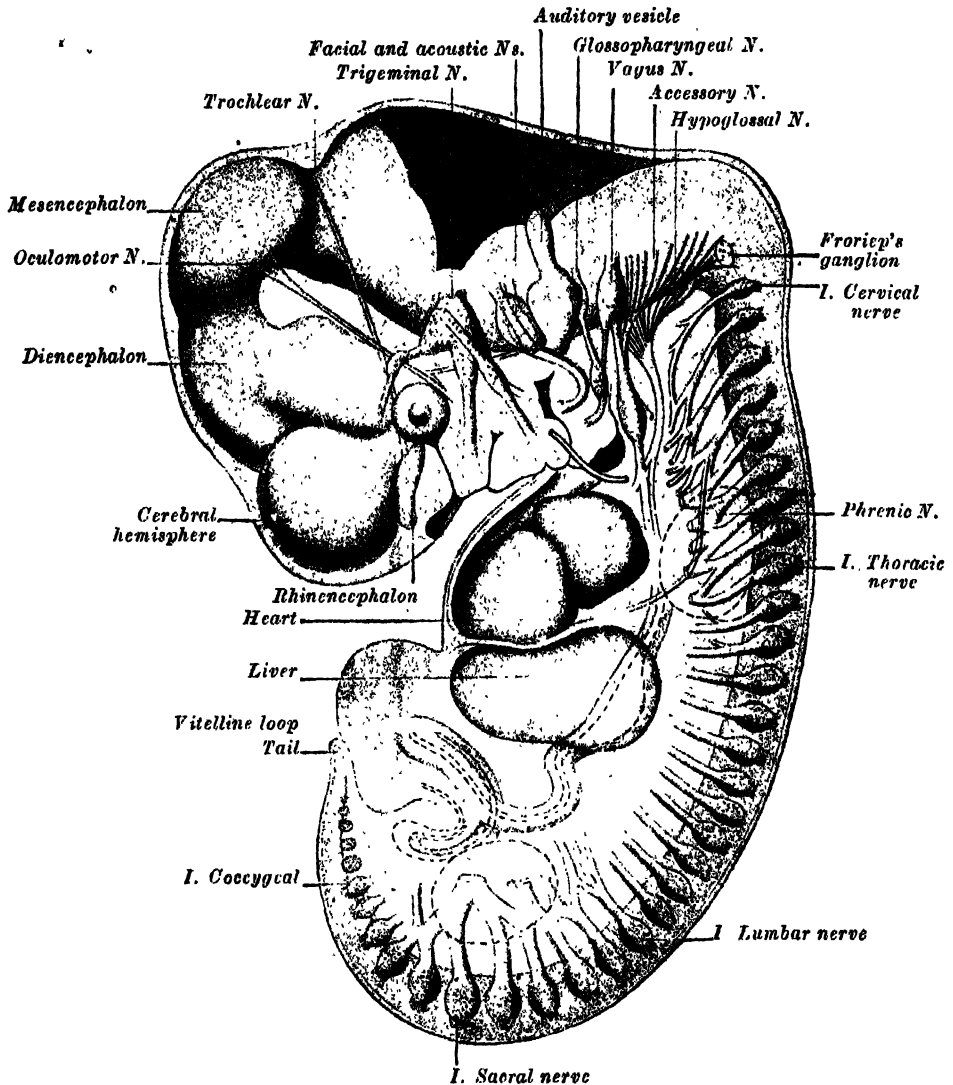
The fibres of the anterior or motor roots are formed by the axons

of the neuroblasts which lie in the ventral part of the mantle layer; these axons grow out through the overlying marginal layer into the myotomes of the primitive segments, and are ultimately aggregated to form the anterior nerve-roots (fig. 128).

The fibres of the posterior roots are developed from the cells of the spinal ganglia. Before the neural groove is closed to form the neural tube a ridge of ectodermal cells, the *ganglion-ridge* or *neural crest* (fig. 131), appears along the prominent margin of each neural fold. When the folds meet in the middle line the two ganglion-ridges fuse and form a wedge-shaped area along the line of closure of the tube. The cells of this area proliferate rapidly opposite the primitive segments and then migrate in a lateral and ventral direction to the sides of the neural tube, where they ultimately form a series of oval-shaped masses, the future spinal ganglia. These ganglia are arranged symmetrically on the two sides of the neural tube and, except in the region of the tail, are equal in number to the primitive segments. The cells of the ganglia, like the cells of the mantle layer, are of two kinds, viz. spongioblasts and neuroblasts. The spongioblasts develop into the neuroglial cells of the ganglia. The neuroblasts, at first round or oval in shape, soon assume the form of spindles the extremities of which gradually elongate into central and peripheral processes. The central processes grow medialwards and, becoming connected with the neural

tube, constitute the fibres of the posterior nerve-roots, while the peripheral processes grow lateralwards to mingle with the fibres of the anterior root in the spinal nerve. As development proceeds the original bipolar form of the cells changes; the two processes become approximated until they ultimately arise from a single stem in a T-shaped manner. The bipolar form is retained in the retina and in the ganglia

FIG. 182.—Reconstruction of the peripheral nerves of a human embryo of 10·2 mm. (After His.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



The abducent nerve is not labelled, but is seen passing forwards to the eye under the mandibular and maxillary nerves.

of the acoustic nerve. More recent observers hold, however, that the T-form is derived from the branching of a single process which grows out from the cell.

Although many embryologists accept the views: (a) that every motor nerve-fibre is an independent outgrowth from a motor nerve-cell and secondarily becomes connected to its special myotome, and (b) that from the sensory nerve-cell a central process grows into the medulla spinalis or into the brain, and a peripheral one outwards to unite with the peripheral sense-organ supplied by the nerve, it is probable that the myotomes and the peripheral sense-organs are from the first connected with the central nervous system, and that this connexion is never lost. In *Lepidosiren*

paradoxa, J. Graham Kerr has traced back the development of the motor nerve trunk to a period in which it is represented by a bridge of soft granular protoplasm connecting the medulla spinalis and myotome at a stage when these structures are in close apposition.* As the myotome is pushed outwards it remains connected with the medulla spinalis by the ever-lengthening strand of nerve, which soon loses its granular protoplasmic character and assumes a fibrillated appearance. A similar condition probably exists regarding the development of sensory nerve-fibres, for Cameron and Milligan† have shown that in early embryonic life the cell-elements of the sense-epithelium of the auditory vesicle are connected with those of the hind-brain by a continuous tract of nucleated protoplasm (syncytium) which is never severed. This syncytium, at first undifferentiated, becomes fibrillated longitudinally to form a continuous tract of nerve-fibres (the future auditory nerve) uniting the sense-epithelium of the auditory organ with the hind-brain.

The anterior and posterior nerve-roots join immediately beyond the spinal ganglion to form the *spinal nerve*, which then divides into anterior, posterior, and visceral divisions. The anterior and posterior divisions proceed directly to their

FIG. 133.—Diagram to illustrate the alar and basal laminae of the brain vesicles. (His.)

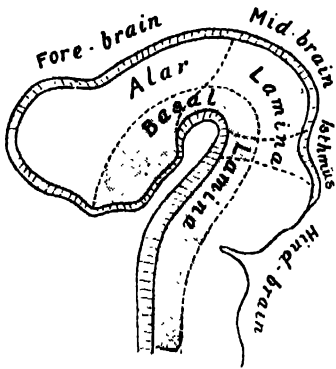
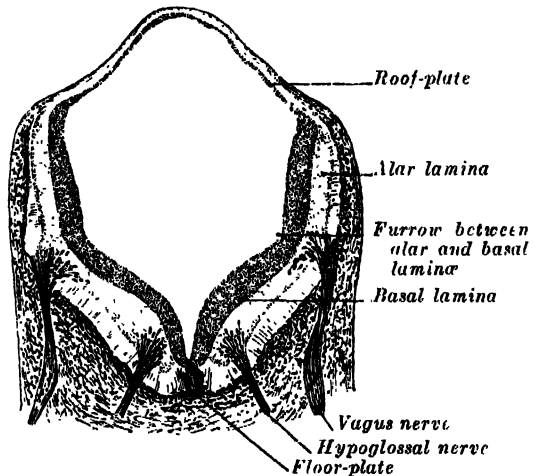


FIG. 134.—Transverse section of the medulla oblongata of a human embryo. $\times 32$. (From Kollmann's *Entwicklungsgeschichte*.)



areas of distribution without further association with ganglion-cells (fig. 132). The visceral divisions are distributed to the thoracic, abdominal, and pelvic viscera, to reach which they pass through the sympathetic trunk, and many of the fibres of these divisions form arborisations around the ganglion-cells of this trunk. Visceral divisions are not given off from all the spinal nerves; they form two groups, viz. (a) *thoracolumbar*, from the first or second thoracic to the second or third lumbar nerves inclusive; and (b) *pelvic*, from the second and third, or third and fourth sacral nerves.

The Brain.—The brain is developed from the anterior end of the neural tube, which at an early period expands into the three primary cerebral vesicles (fig. 81). These are marked off from each other by intervening constrictions, and are named the *rhombencephalon* or *hind-brain*, the *mesencephalon* or *mid-brain*, and the *prosencephalon* or *fore-brain*—the first being continuous with the medulla spinalis. As the result of unequal growth of the different parts of the brain three flexures are formed and the brain bends on itself in a somewhat zigzag fashion; the two earliest flexures are concave ventrally and are associated with corresponding flexures of the whole head. The first appears in the region of the mid-brain, and is named the *ventral cephalic flexure* (fig. 137); the fore-brain bends in a ventral direction around the anterior end of the notochord and fore-gut until its floor lies almost

* 'On some points in the early development of motor nerve-trunks and myotomes in *Lepidosiren paradoxa*,' *Transactions of the Royal Society of Edinburgh*, vol. xli. part i. 1903-4.

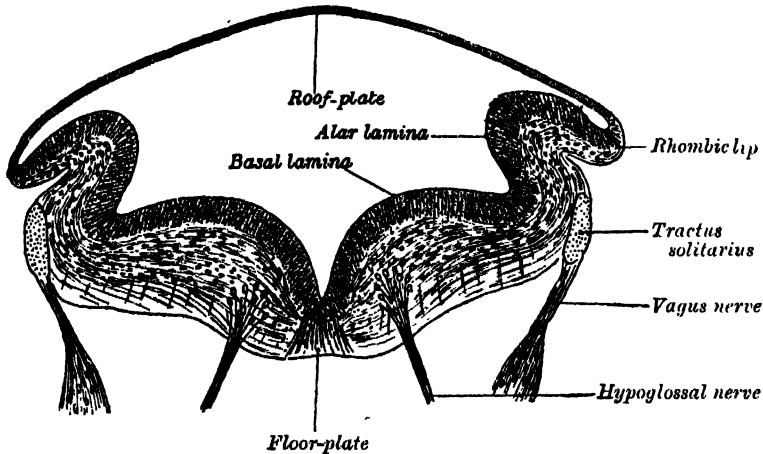
† 'The development of the auditory nerve in vertebrates,' *Journal of Anatomy and Physiology*, vol. xliiv.

parallel with that of the hind-brain. The mid-brain is for a time the most prominent part of the brain, since its dorsal surface corresponds with the convexity of the flexure. The second bend appears at the junction of the hind-brain and medulla spinalis, and is termed the *cervical flexure* (fig. 137). It increases from the third to the end of the fifth week, when the hind-brain forms nearly a right angle with the medulla spinalis; after the fifth week erection of the head takes place and the cervical flexure diminishes and disappears. The third bend is named the *pontine flexure* (fig. 139), because it is found in the region of the future pons (Varolii). It differs from the other two in that (a) its convexity is forwards, and (b) it does not affect the head.

The lateral walls of the brain-tube, like those of the medulla spinalis, are divided by internal furrows into dorsal or alar and ventral or basal laminæ (figs. 133, 134).

The **rhombencephalon** or **hind-brain**.—The cavity of the hind-brain becomes the fourth ventricle. At the time when the ventral cephalic flexure makes its appearance, the hind-brain exceeds in length the combined lengths of the other two vesicles. Anteriorly it exhibits a constriction, the *isthmus rhombencephali* (fig. 133, Isthmus), which is best seen when the brain is viewed from the dorsal aspect. From the isthmus the brachia conjunctiva of the cerebellum and the

FIG. 135.—Transverse section of the medulla oblongata of a human embryo. (After His.)

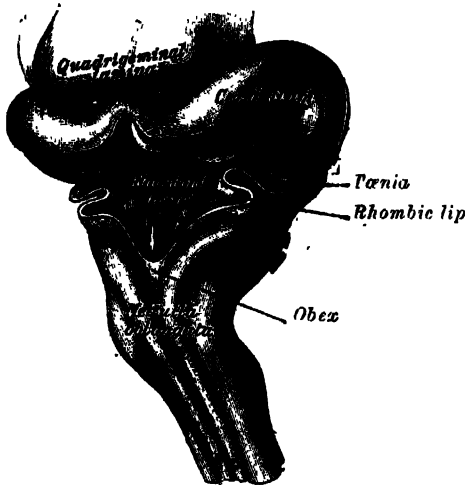


anterior medullary velum are formed. The rest of the hind-brain consists of two parts, viz.: an upper, called the *metencephalon*, and a lower, the *myelencephalon*. The cerebellum is developed by a thickening of the roof, and the pons by a thickening in the floor and lateral walls of the metencephalon. The floor and lateral walls of the myelencephalon are thickened to form the medulla oblongata; its roof remains thin, and, retaining to a great extent its epithelial nature, is expanded in a lateral direction. Later, by the growth and backward extension of the cerebellum, the roof is folded inwards towards the cavity of the fourth ventricle; it assists in completing the dorsal wall of this cavity, and is also invaginated to form the ependymal covering of the choroid plexuses of the fourth ventricle. Above it is continuous with the posterior medullary velum; below, with the obex and ligulæ.

The development of the *medulla oblongata*, though resembling that of the medulla spinalis, exhibits one or two interesting modifications. At an early stage the myelencephalon consists of two lateral walls, connected across the middle line by floor- and roof-plates (figs. 134 and 135). Each lateral wall consists of an alar and a basal lamina, separated by an internal furrow, the remains of which are represented in the adult brain by the sulcus limitans on the rhomboid fossa. The contained cavity is more or less triangular in section, the base being formed by the roof-plate, which is thin and greatly expanded transversely. Pear-shaped neuroblasts are developed in the alar and basal laminæ, and their narrow stalks are elongated to form the axis-cylinders of the nerve-fibres. Opposite the furrow or boundary between the alar and basal laminæ a bundle of nerve-fibres attaches itself to the outer surface of the alar lamina. This is named the *tractus solitarius*

(fig. 135), and is formed by the sensory fibres of the glossopharyngeal and vagus nerves. It is the homologue of the *oval bundle* seen in the medulla spinalis, and, like it, is developed by an ingrowth of fibres from the ganglia of the neural crest.

FIG. 136.—Hind-brain of a human embryo of three months, viewed from behind and partly from the right side. (From model by His.)



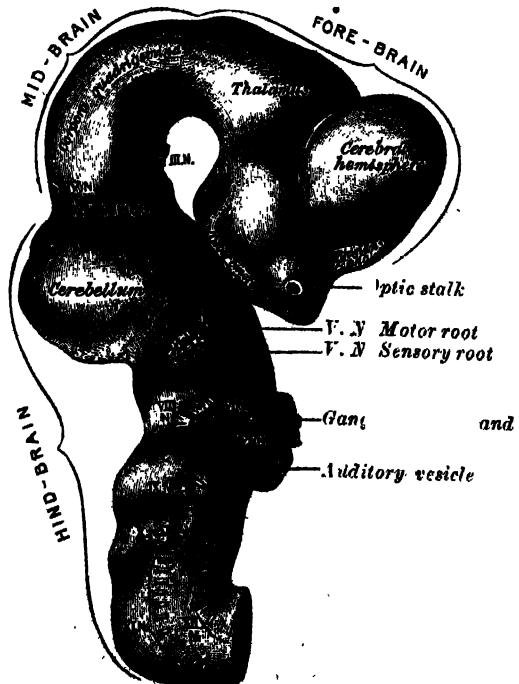
alar lamina and its rhombic lip, neuroblasts migrate into the basal lamina, where some are aggregated to form the olivary nuclei, while many send their axis-cylinders through the floor-plate to the opposite side, and thus constitute the rudiment of the raphe of the medulla oblongata. By means of this thickening of the ventral portion, the motor nuclei are buried deeply in the interior, and in the adult are found close to the rhomboid fossa. This is still further accentuated: (a) by the development of the pyramids, which are formed about the fourth month by the downward growth of the motor fibres from the cerebral cortex; and (b) by the fibres which pass to and from the cerebellum. On the rhomboid fossa six temporary furrows or *rhombic grooves* appear. They bear a definite relationship to certain of the cerebral nerves; thus, from before backwards, the first and second grooves overlie the nucleus of the trigeminal; the third, that of the facial; the fourth, that of the abducent; the fifth, that of the glossopharyngeal; and the sixth, that of the vagus.

The pons is developed from the ventrolateral wall of the metencephalon by a process similar to that which has been described for the medulla oblongata.

At first it is applied to the outer surface of the alar lamina, but is soon buried by the growth over it of the neighbouring parts. By the fifth week the dorsal part of the alar lamina bends in a lateral direction along its entire length, to form what is termed the *rhombic lip* (figs. 135, 139). Within a few days this lip adheres to, and unites with, the outer surface of the main part of the alar lamina, and so covers in the tractus solitarius and also the spinal root of the trigeminal nerve.

Neuroblasts accumulate in the mantle layer; those in the basal lamina correspond with the cells in the anterior grey column of the medulla spinalis, and, like them, give origin to motor nerve-fibres; in the medulla oblongata they are, however, arranged in groups or nuclei, instead of forming a continuous column. From the

FIG. 137.—Exterior of the brain of a human embryo of four and a half weeks. (From model by His.)



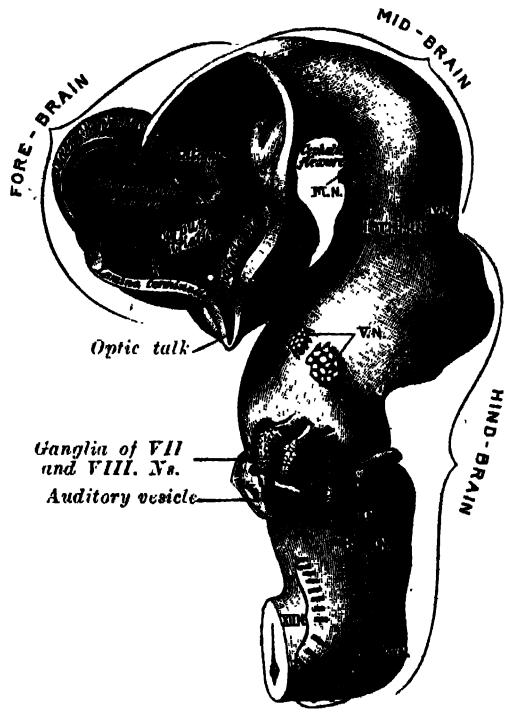
The *cerebellum* is developed in the roof of the anterior part of the hind-brain (figs. 136 to 141). The alar laminae of this part increase in thickness and form two lateral plates which fuse in the middle line and produce a thick lamina which roofs in the upper part of the cavity of the hind-brain vesicle; this lamina constitutes the rudiment of the cerebellum, the outer surface of which is originally smooth and convex. The flocculus and nodule are developed from the rhombic lip, and are recognisable as separate portions before any of the other cerebellar lobules. The fissures of the cerebellum appear first in the vermis and floccular region, and traces of them are found during the third month; the fissures on the cerebellar hemispheres do not appear till the fifth month. The primitive fissures are not developed in the order of their relative size in the adult—thus the horizontal sulcus in the fifth month is merely a shallow groove. The best marked of the early fissures are: (a) the *fissura prima* between the developing culmen and declive, and (b) the *fissura secunda* between the future pyramid and uvula. The groove produced by the bending over of the rhombic lip is here known as the *floccular fissure*; when the two lateral walls fuse, the right and left floccular fissures join in the middle line, and their central part becomes the *postnodular fissure*.

On the ventricular surface of the cerebellar lamina a transverse furrow, the *incisura fastigii*, appears and then deepens to form the tent-like recess of the roof of the fourth ventricle. The rudiment of the cerebellum at first projects in a dorsal direction; but, by the backward growth of the cerebrum, it is folded downwards and somewhat flattened, and the thin roof-plate of the fourth ventricle, originally continuous with the posterior border of the cerebellum, is projected inwards towards the cavity of the ventricle.

The *mesencephalon* or *mid-brain*.—The mid-brain (figs. 137 to 141) exists for a time as a thin-walled cavity of some size, and is separated by slight constrictions from the isthmus rhombencephali behind, and from the fore-brain in front. Its cavity becomes relatively reduced in diameter, and forms the cerebral aqueduct of the adult brain. The basal laminae of the hind-brain increase in thickness to form the cerebral peduncles, which are at first of small size, but rapidly enlarge after the fourth month. Many of the neuroblasts of these laminae are grouped in relation to the sides and floor of the cerebral aqueduct, and constitute the nuclei of the oculomotor and trochlear nerves, and of the mesencephalic root of the trigeminal nerve; others are aggregated to form the red nuclei. By a similar thickening process the alar laminae are developed into the quadrigeminal lamina. The dorsal part of the wall expands, and for a time presents an internal median furrow and a corresponding external ridge; these, however, disappear, and the latter is replaced by a groove. Subsequently two oblique furrows extend medialwards and backwards, and the thickened lamina is thus subdivided into the superior and inferior colliculi.

The *prosencephalon* or *fore-brain*.—A transverse section of the early fore-brain shows the same parts as are displayed in similar sections of the medulla spinalis and medulla oblongata, viz. a pair of thick lateral walls connected by thin floor- and roof-plates. Moreover, each lateral wall is divided into a dorsal or alar and a ventral or basal lamina separated internally by a furrow termed

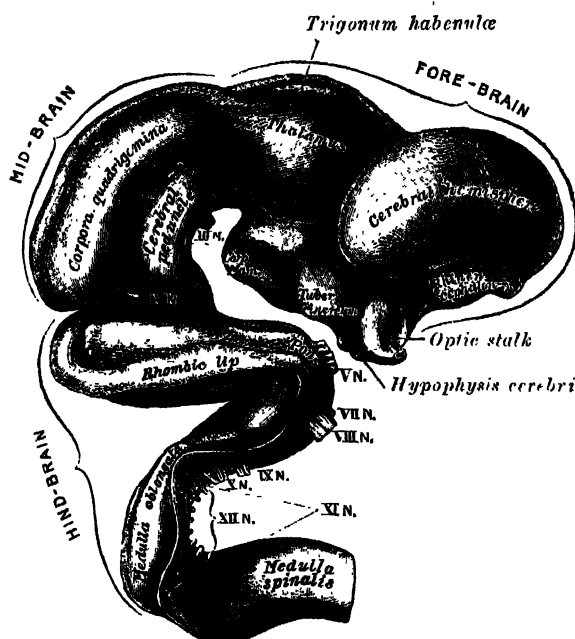
FIG. 138.—Brain of a human embryo of four and a half weeks, showing the interior of fore-brain. (From model by His.)



the *sulcus of Monroe*. This sulcus ends anteriorly at the medial end of the optic stalk, and in the adult brain is retained as a slight groove extending backwards from the interventricular foramen to the cerebral aqueduct.

At a very early period—in some animals before the closure of the cranial part of the neural tube—two lateral diverticula, the *optic vesicles*, appear, one on either side of the fore-brain; for a time they communicate with the cavity of the fore-brain by relatively wide openings. The peripheral parts of the vesicles expand, while the proximal parts are reduced to tubular stalks, the *optic stalks*. The optic vesicle gives rise to the retina and the epithelium on the back of the ciliary body and iris; the optic stalk is invaded by nerve-fibres to form the optic nerve. The fore-brain then grows forwards, and from the alar laminae of this front portion the cerebral hemispheres originate as diverticula which rapidly expand to form two large pouches, one on either side. The cavities of these diverticula are the rudiments of the lateral ventricles; they communicate with the median part of the fore-brain cavity by

FIG. 139.—Exterior of the brain of a human embryo of five weeks. The roof of the hind-brain has been removed. (From model by His.)



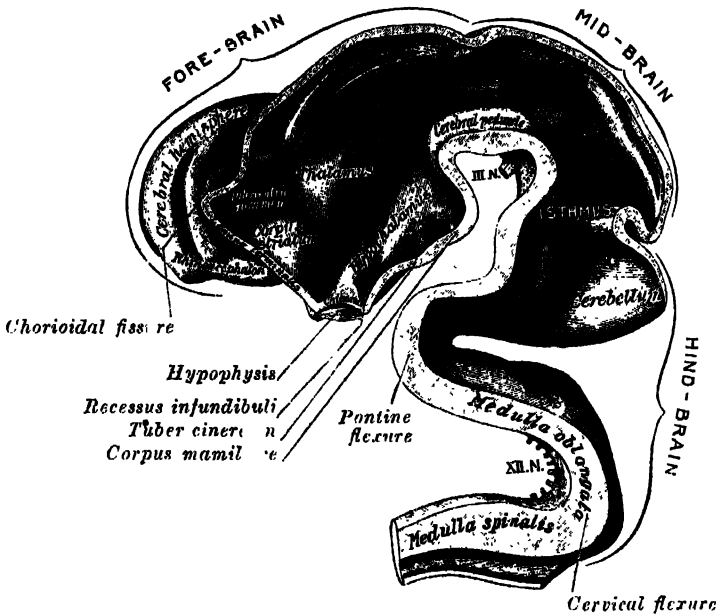
relatively wide openings, which ultimately form the interventricular foramen (foramen of Monroe). The median portion of the wall of the fore-brain vesicle consists of a thin lamina, the *lamina terminalis* (figs. 141, 144), which stretches from the interventricular foramen to the recess at the base of the optic stalk. The anterior part of the fore-brain, including the rudiments of the cerebral hemispheres, is named the *telencephalon*, and the posterior portion the *diencephalon*; both contribute to the formation of the third ventricle.

The diencephalon.—From the alar lamina of the diencephalon, the thalamus, metathalamus, and epithalamus are developed. The *thalamus* (figs. 137 to 141) arises as a thickening which involves the anterior two-thirds of the alar lamina. The two thalami are visible, for a time, on the surface of the brain, but are subsequently hidden by the cerebral hemispheres which grow backwards over them. The thalami extend medialwards and gradually narrow the interval between them into a slit-like cavity which forms the greater part of the third ventricle; their medial surfaces ultimately adhere, in part, to each other, and the *intermediate mass* of the ventricle is developed across the area of contact. The *metathalamus* comprises the medial and lateral geniculate bodies which originate as slight outward bulgings of the alar lamina. In the adult the lateral geniculate body appears as an eminence on the lateral part of the posterior end of the thalamus, while the medial lies under cover of the pulvinar

of the thalamus. The *epithalamus* includes the pineal body, the posterior commissure, and the trigonum habenulæ. The pineal body arises as a bilateral evagination of the roof-plate immediately in front of the mid-brain; only the left portion persists in vertebrates, and it becomes solid with the exception of its proximal part, which forms the recessus pinealis. The pineal body consists essentially of (a) a distal part representing a rudimentary eye, and (b) a proximal part which is glandular in nature; only this latter portion is represented in man. The posterior commissure is formed by the ingrowth of fibres into the depression behind and below the pineal evagination, and the trigonum habenulæ is developed in front of the pineal recess.

From the basal laminæ of the diencephalon the *pars mamillaris hypothalami* is developed; this comprises the corpora mamillaria and the posterior part of the tuber cinereum. The corpora mamillaria arise as a single thickening, which is divided by a median furrow during the third month.

FIG. 140.—Interior of the brain of a human embryo of five weeks. The roof of the hind-brain has been removed. (From model by His.)



The roof-plate of the diencephalon, in front of the pineal body, remains thin and epithelial in character, and is subsequently invaginated by the chorioid plexuses of the third ventricle.

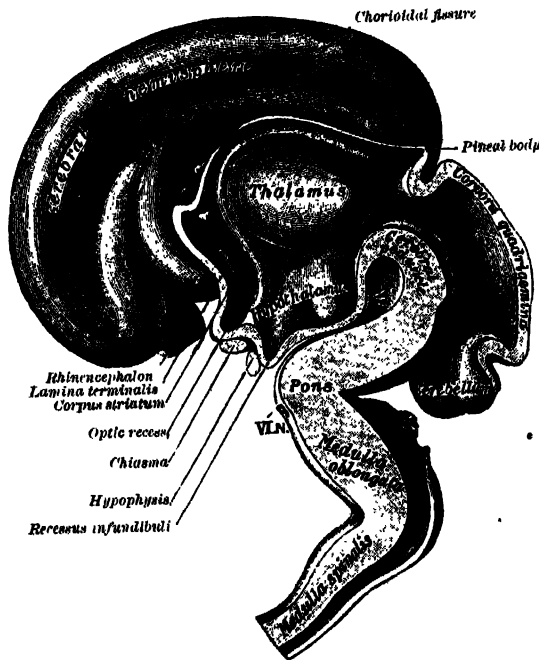
The *telencephalon*.—This consists of a median portion and two lateral diverticula. The median portion forms the anterior part of the cavity of the third ventricle, and is closed below and in front by the lamina terminalis. The lateral diverticula consist of outward pouchings of the alar laminæ; the cavities represent the future lateral ventricles, and their walls the nervous matter of the cerebral hemispheres. The roof-plate of the telencephalon remains thin, and is continuous in front with the lamina terminalis and behind with the roof-plate of the diencephalon. In the basal laminæ and floor-plate the *pars optica hypothalami* is developed; this comprises the anterior part of the tuber cinereum, the infundibulum and posterior lobe of the hypophysis, and the optic chiasma. The anterior part of the tuber cinereum is derived from the posterior part of the floor of the telencephalon; the infundibulum and posterior lobe of the hypophysis arise as a downward diverticulum from the floor. The most dependent part of the diverticulum becomes solid and forms the posterior lobe of the hypophysis; the anterior lobe of the hypophysis is developed from a diverticulum of the ectodermal lining of the stomodæum (page 132). The optic chiasma is formed by the meeting and partial

decussation of the optic nerves, which subsequently grow backwards as the optic tracts and end in the diencephalon.

The *cerebral hemispheres* arise as diverticula of the alar laminae of the telencephalon (figs. 137 to 141); they increase rapidly in size and ultimately overlap the structures developed from the mid- and hind-brains. This great expansion of the hemispheres is a characteristic feature of the brains of mammals, and attains its maximum development in the brain of man. Elliot Smith divides each cerebral hemisphere into three fundamental parts, viz. the rhinencephalon, the corpus striatum, and the neopallium.

The *rhinencephalon* (figs. 139 to 142) represents the oldest part of the telencephalon, and forms almost the whole of the hemisphere in fishes, amphibians, and reptiles. In man it is feebly developed in comparison with the rest of the hemisphere, and comprises the following parts, viz. the olfactory lobe (consisting of the

FIG. 141.—Median sagittal section of brain of a human embryo of three months. (From model by His.)



olfactory tract and bulb, and the trigonum olfactorium), the anterior perforated substance, the septum pellucidum, the subcallosal, supracallosal, and dentate gyri, the fornix, the hippocampus, and the uncus. The rhinencephalon appears as a longitudinal elevation, with a corresponding internal furrow, on the under surface of the hemisphere close to the lamina terminalis; it is separated from the lateral surface of the hemisphere by a furrow, the *external rhinal fissure*, and is continuous behind with that part of the hemisphere which will ultimately form the anterior end of the temporal lobe. The elevation is divided by a groove into an anterior and a posterior part. The anterior grows forwards as a hollow stalk the lumen of which is continuous with the anterior part of the ventricular cavity. During the third month the stalk becomes solid and forms the rudiment of the olfactory bulb and tract; a strand of gelatinous tissue in the interior of the bulb indicates the position of the original cavity. From the posterior part the anterior perforated substance and the pyriform lobe are developed; at the beginning of the fourth month the latter forms a curved elevation continuous behind with the medial surface of the temporal lobe, and consisting, from before backwards, of the gyrus olfactorius lateralis, gyrus ambiens, and gyrus semilunaris, parts which in the adult brain are represented by the lateral root of the olfactory tract and the uncus. The

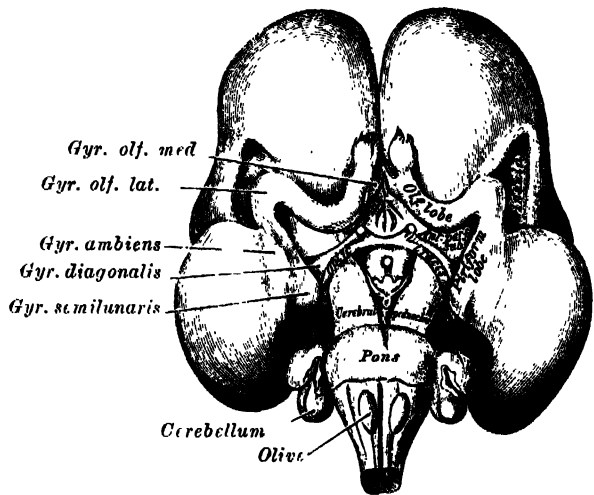
position and connexions of the remaining portions of the rhinencephalon are described with the anatomy of the brain.

The *corpus striatum* (figs. 138, 140) appears in the fourth week as a triangular thickening of the floor of the telencephalon between the optic recess and the interventricular foramen, and continuous behind with the thalamic part of the diencephalon. It increases in size, and by the second month forms a swelling in the floor of the future lateral ventricle; this swelling reaches as far as the posterior end of the primitive hemisphere, and when this part of the hemisphere grows backwards and downwards to form the temporal lobe, the posterior part of the corpus striatum is carried into the roof of the inferior horn of the ventricle, where it is seen as the tail of the caudate nucleus in the adult brain. During the fourth and fifth months the corpus striatum becomes incompletely subdivided by the fibres of the internal capsule into two masses, an inner, the caudate nucleus, and an outer, the lentiform nucleus. In front, the corpus striatum is continuous with the anterior perforated substance; laterally it is confluent for a time with that portion of the wall of the vesicle which is developed into the insula, but this continuity is subsequently interrupted by the fibres of the external capsule.

The *neopallium* (fig. 143) forms the remaining, and by far the greater part of the cerebral hemisphere. It consists, at an early stage, of a relatively large, more or less hemispherical cavity—the primitive lateral ventricle—enclosed by a thin wall from which the cortex of the hemisphere is developed. The vesicle expands in all directions, but more especially upwards and backwards, so that by the third month the hemispheres cover the diencephalon, by the sixth they overlap the mid-brain and by the eighth the hind-brain.

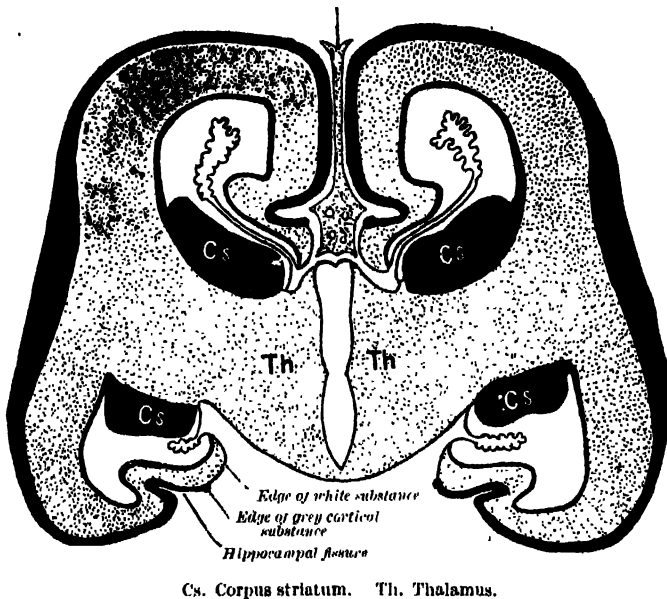
The median lamina uniting the two hemispheres does not share in their expansion, and thus the hemispheres are separated by a deep cleft, the forerunner of the longitudinal fissure, and this cleft is occupied by a septum of mesodermal tissue which constitutes the primitive falx cerebri. Coincidentally with the expansion of the vesicle, its cavity is drawn out into three prolongations which represent the horns of the future lateral ventricle; the hinder end of the vesicle is carried downwards and forwards and forms the inferior horn; the posterior horn is produced somewhat later, in association with the backward growth of the occipital lobe of the hemisphere. The roof-plate of the primitive fore-brain remains thin and of an epithelial character; it is invaginated into the lateral ventricle along the medial wall of the hemisphere. This invagination constitutes the chorioidal fissure, and extends from the interventricular foramen to the posterior end of the vesicle. Mesodermal tissue, continuous with that of the pia mater, and carrying blood-vessels with it, spreads between the two layers of the invaginated fold and forms the rudiment of the tela chorioidea; the margins of the tela become highly vascular and form the chorioid plexuses which for some months almost completely fill the ventricular cavities; the tela at the same time invaginates the epithelial roof of the diencephalon and there forms the chorioid plexuses of the third ventricle. By the downward and forward growth of the posterior end of the vesicle to form the temporal lobe the chorioidal fissure finally reaches from the interventricular foramen to the extremity of the inferior horn of the ventricle.

FIG. 142.—Inferior surface of the brain of an embryo at the beginning of the fourth month. (Kollmann.)



Parallel with but above and in front of the chorioidal fissure the medial wall of the cerebral vesicle becomes folded lateralwards and gives rise to the *hippocampal fissure* on the medial surface and to a corresponding elevation, the *hippocampus*, within the ventricular cavity. The grey or ganglionic covering of the wall of the vesicle ends at the inferior margin of the fissure in a thickened edge; beneath this the marginal or reticular layer (future white substance) is exposed and its lower thinned edge is continuous with the epithelial invagination covering the chorioid plexus (fig. 143). As a result of the later downward and forward growth of the temporal lobe the hippocampal fissure and the parts associated with it extend from the interventricular foramen to the end of the inferior horn of the ventricle. The thickened edge of grey substance becomes the gyrus dentatus, the fasciola cinerea and the supra- and sub-callosal gyri, while the free edge of the white substance forms

FIG. 143.—Diagrammatic coronal section of the brain to show relations of the neopallium. (After His.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



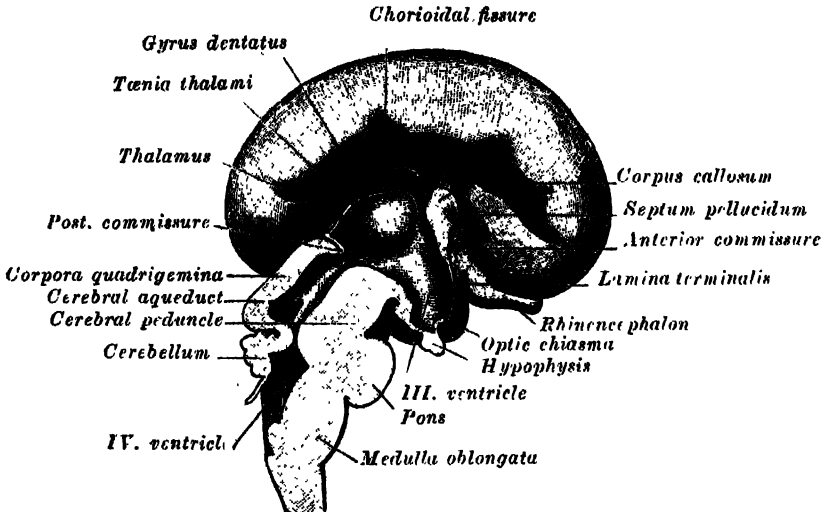
the fimbria hippocampi and the body and crus of the fornix. The corpus callosum is developed within the arch of the hippocampal fissure, and the upper part of the fissure forms, in the adult brain, the callosal fissure on the medial surface of the hemisphere.

The commissures (fig. 144).—The development of the posterior commissure has already been referred to (page 95). The great commissures of the hemispheres, viz. the corpus callosum, the fornix, and anterior commissure, arise from the lamina terminalis. About the fourth month a small thickening appears in this lamina, immediately in front of the interventricular foramen. The lower part of this thickening is soon separated, and nerve-fibres appear in it to form the anterior commissure. The upper part continues to grow with the hemispheres, and is invaded by two sets of fibres. Transverse fibres, extending between the hemispheres, pass into its dorsal part, which is now differentiated as the corpus callosum. Into the ventral part longitudinal fibres from the hippocampus pass to the lamina terminalis, and through that structure to the corpora mamillaria; these fibres constitute the fornix. A small portion, lying antero-inferiorly between the corpus callosum and fornix, is not invaded by the commissural fibres; it remains thin, and later, a cavity, the cavity of the septum pellucidum, forms in its interior.

Fissures and Sulci.—The outer surface of the cerebral hemisphere is at first smooth, but later exhibits a number of elevations or convolutions, separated from

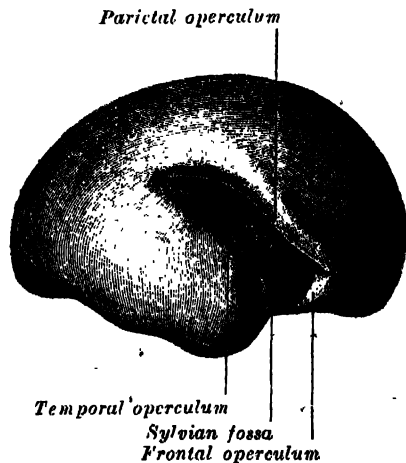
each other by fissures and sulci, most of which make their appearance during the sixth or seventh months of foetal life. The term *fissure* is applied to such grooves as

FIG. 144.—Median sagittal section of the brain of a human embryo of four months. (Marchand.)



involve the entire thickness of the cerebral wall, and produce corresponding eminences in the lateral ventricle, while the *sulci* affect only the superficial part of the wall, and produce no such eminences. The fissures comprise the *chorioid* and *hippocampal* already described, and two others, viz. the *calcarine* and *collateral*, which give rise to the swellings known respectively as the *calcar avis* and the *collateral eminence* in the lateral ventricle. Of the sulci the following may be referred to, viz. the *central sulcus* (*fissure of Rolando*), which is developed in two parts; the *intraparietal sulcus* in four parts; and the *cingulate sulcus* in two or three parts. The *lateral cerebral* or *Sylvian fissure* differs from the others in its mode of development. About the third month a depression, the *Sylvian fossa*, appears on the lateral surface of the hemisphere (fig. 145); this fossa corresponds with the position of the corpus striatum, and its floor is moulded to form the cortex of the insula. The intimate connexion which exists between the deep surface of the cortex of the insula and the corpus striatum prevents the insular part of the hemisphere wall from expanding at the same rate as the portions which surround it, with the result that they gradually grow over and cover the insula, and constitute the temporal, parietal, frontal, and orbital opercula of the adult brain. The frontal and orbital opercula are the last to form, but by the end of the first year after birth the insula is completely submerged by the approximation of the opercula. The fissures separating the opposed margins of the opercula constitute the composite lateral cerebral fissure.

FIG. 145.—(Lateral surface of the cerebral hemisphere of a human embryo of about five months.



If a section across the wall of the hemisphere about the sixth week be examined microscopically it will be found to consist of a thin marginal or reticular layer, a thick ependymal layer, and a thin intervening mantle layer. Neuroblasts from the ependymal and mantle layers migrate into the deep part of the marginal layer and form the cells of the cerebral cortex. By the sixth month the middle cell-lamina has attained one-half, and the inner cell-lamina three-fourths of their adult thickness; the outer cell-lamina is the last to develop. The nerve fibres which form the underlying white substance of the hemispheres consist at first of outgrowths from the cells of the corpora striata and thalami; the fibres from the cells of the cortex are added later. Medullation of these fibres begins about the time of birth and continues until puberty.

A summary of the parts derived from the brain vesicles is given in the following table:—

Rhombencephalon or hind-brain	1. Myelencephalon	Medulla oblongata. Lower part of fourth ventricle.
	2. Metencephalon	Pons. Cerebellum. Intermediate part of fourth ventricle.
	3. Isthmus rhombencephali	Anterior medullary velum. Brachia conjunctiva cerebelli. Upper part of fourth ventricle.
Mesencephalon or mid-brain		Cerebral peduncles. Lamina quadrigemina. Cerebral aqueduct.
Prosencephalon or fore-brain	1. Diencephalon	Thalamus. Metathalamus. Epithalamus. Pars mammillaris hypothalami. Posterior part of third ventricle.
		Anterior part of third ventricle.
	2. Telencephalon	Pars optica hypothalami. Cerebral hemispheres. Lateral ventricles. Interventricular foramen.

The cerebral nerves.—With the exception of the olfactory, optic, and acoustic nerves, which will be specially considered, the cerebral nerves are developed in a similar manner to the spinal nerves (page 88). The sensory or afferent nerves are derived from the cells of the ganglion-rudiments of the neural crest. The central processes of these cells form the roots of the nerves, while the peripheral processes constitute their fibres of distribution (fig. 132). It has been seen, in considering the development of the medulla oblongata (page 91), that the *tractus solitarius* (fig. 147), derived from the fibres which grow inwards from the ganglion-rudiments of the glossopharyngeal and vagus nerves, is the homologue of the *oval bundle* in the medulla spinalis which has its origin in the posterior nerve-roots. The motor nerves arise as outgrowths of the neuroblasts situated in the basal laminae of the mid- and hind-brain. While, however, the spinal motor nerve-roots arise in one series from the basal lamina, the cerebral motor nerves are grouped into two sets, according as they spring from the medial or lateral parts of the basal lamina. To the former set belong the oculo-motor, trochlear, abducent, and hypoglossal nerves; to the latter, the accessory, and the motor fibres of the trigeminal, facial, glossopharyngeal, and vagus nerves (figs. 146, 147).

The sympathetic system.—The ganglion-cells of the *sympathetic system* are derived from the cells of the neural crests. These crests move forwards along the sides of the neural tube and become segmented to form the spinal ganglia; certain cells detach themselves from the ventral margins of the crests and migrate towards the sides of the aorta, where some of them are grouped to form the ganglia of the sympathetic trunks, while others undergo a further migration and form

the ganglia of the prevertebral and visceral plexuses. The ciliary, sphenopalatine, otic, and submaxillary ganglia are probably formed by groups of cells which have migrated from that part of the neural crest which gives rise to the semilunar ganglion.

Chromaffin organs.—The tissue from which the sympathetic ganglia are formed is at first a syncytium of cells termed sympathochromaffin cells, but later two kinds of cells become differentiated from it; the smaller cells (sympathoblasts) are transformed into the sympathetic nerve-cells, the larger become chromaffin cells, and, separating from the others, accumulate to form the chromaffin organs. In the gangliated trunk of the sympathetic the chromaffin bodies are situated in depressions in the ganglia. In connexion with certain, but not all, of the secondary plexuses of the sympathetic system chromaffin organs are found; the largest members of this series are the *aortic bodies*, which lie along the sides of the abdominal aorta between the superior mesenteric and common iliac arteries; to this group belong also the *carotid glomera* (carotid bodies). After birth the chromaffin organs degenerate and can no longer be isolated by gross dissection, but chromaffin tissue can be recognised with the microscope in the sites originally occupied by them.

The suprarenal glands.—Each suprarenal gland consists of a cortical portion derived from the coelomic epithelium and a medullary portion originally composed of sympathochromaffin tissue. The cortical portion is first recognisable about

FIG. 146.—Transverse section of the medulla oblongata of a human embryo. $\times 32$. (From Kollmann's *Entwicklungsgeschichte*.)

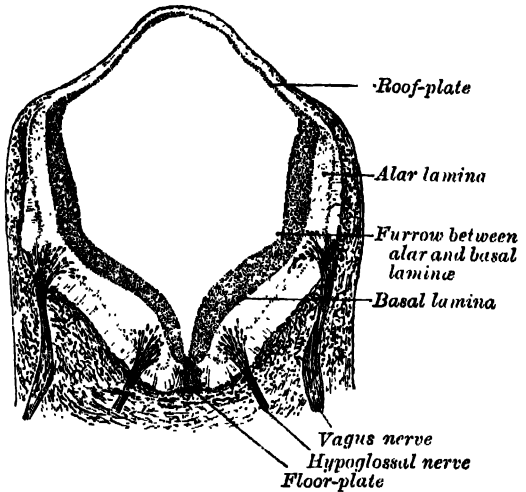
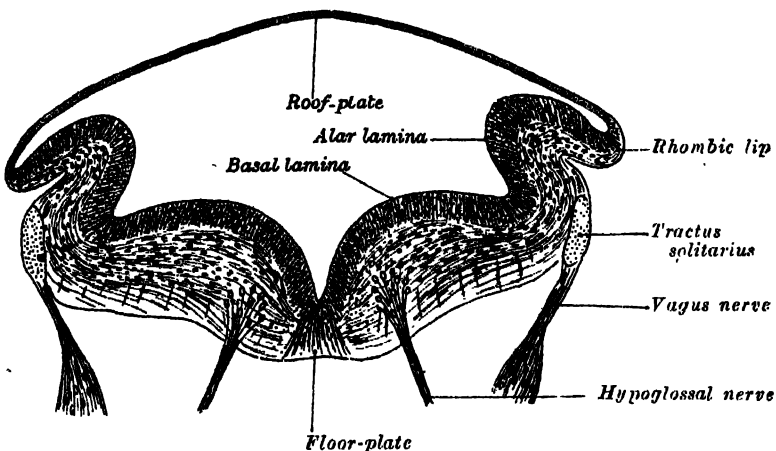


FIG. 147.—Transverse section of the medulla oblongata of a human embryo. (After His.)

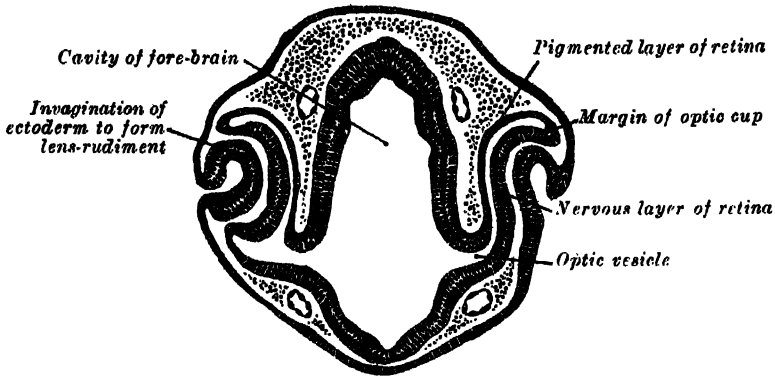


the beginning of the fourth week as a series of buds from the coelomic cells at the root of the mesentery. Later it becomes completely separated from the coelomic epithelium and forms a suprarenal ridge projecting into the coelom between the mesonephros and the root of the mesentery. Into this cortical portion cells from the neighbouring masses of sympathochromaffin tissue migrate along the line of its central vein to reach and form the medullary portion of the gland.

The Nose.—The development of the nose has already been considered (pages 79 to 82).

The *olfactory nerves* are developed from the cells of the ectoderm which line the olfactory pits; these cells undergo proliferation and give rise to what are termed

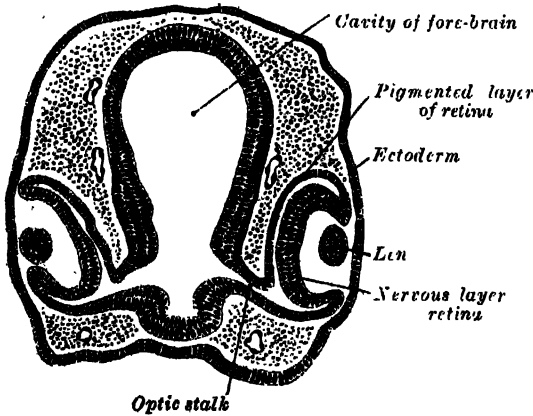
FIG. 148.—Transverse section of the head of a chick embryo of forty-eight hours' incubation. (From Duval's Atlas d'Embryologie.)



the *olfactory cells* of the nose. The axons of these cells grow into the overlying olfactory bulb and form the olfactory nerves.

The Eye.—The rudiments of the eyes appear as a pair of hollow diverticula from the lateral aspects of the fore-brain. These diverticula are visible before the closure of the anterior neuropore; after its closure they are known as the *optic vesicles*. They project towards the sides of the head, and the peripheral part of

FIG. 149.—Transverse section of the head of a chick embryo of fifty-two hours' incubation. (From Duval's Atlas d'Embryologie.)



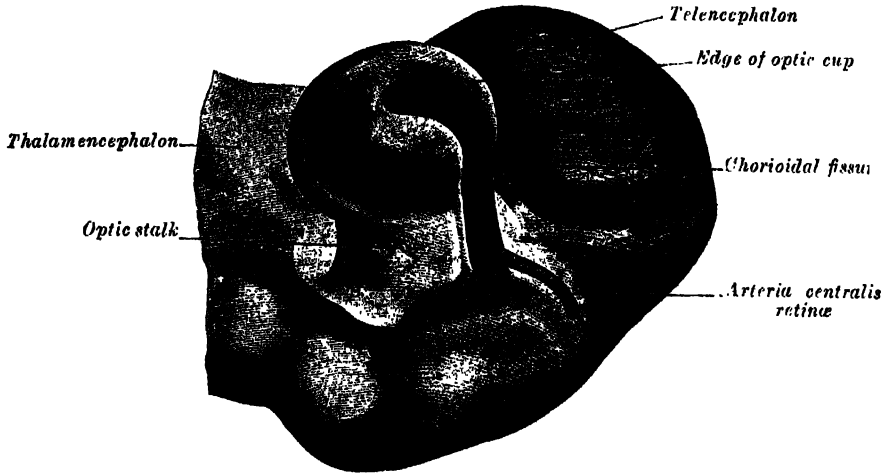
each expands to form the *optic bulb*, while the proximal part remains narrow and constitutes the *optic stalk* (figs. 148, 149). A small area of ectoderm overlying the optic bulb becomes thickened, and ultimately separated as the *lens vesicle*, or rudiment of the crystalline lens. The outer wall of the optic bulb increases in thickness and undergoes invagination so that the bulb is converted into a cup, the *optic cup*, consisting of two strata of cells (fig. 149). These two strata are continuous with each other at the cup-margin, which ultimately overlaps the front of the lens and reaches as far forward as the future aperture of the pupil. The invagination

is not limited to the outer wall of the bulb, but involves also its postero-inferior surface and extends in the form of a groove for some distance along the optic stalk, and thus, for a time, a gap or fissure, the *chorioid fissure*, exists in the lower part of the cup (fig. 150). Through the groove and fissure the mesoderm extends into the optic stalk and cup, and in this mesoderm an artery is developed; during the seventh week the groove and fissure close, and the artery forms the central artery of the retina. Sometimes the chorioid fissure persists, and when this occurs the chorioid and iris in the region of the fissure remain undeveloped, giving rise to the condition known as *congenital coloboma* of the chorioid or iris.

The retina is developed from the optic cup. The outer stratum of the cup persists as a single layer of cells; these cells assume a columnar shape, acquire pigment,

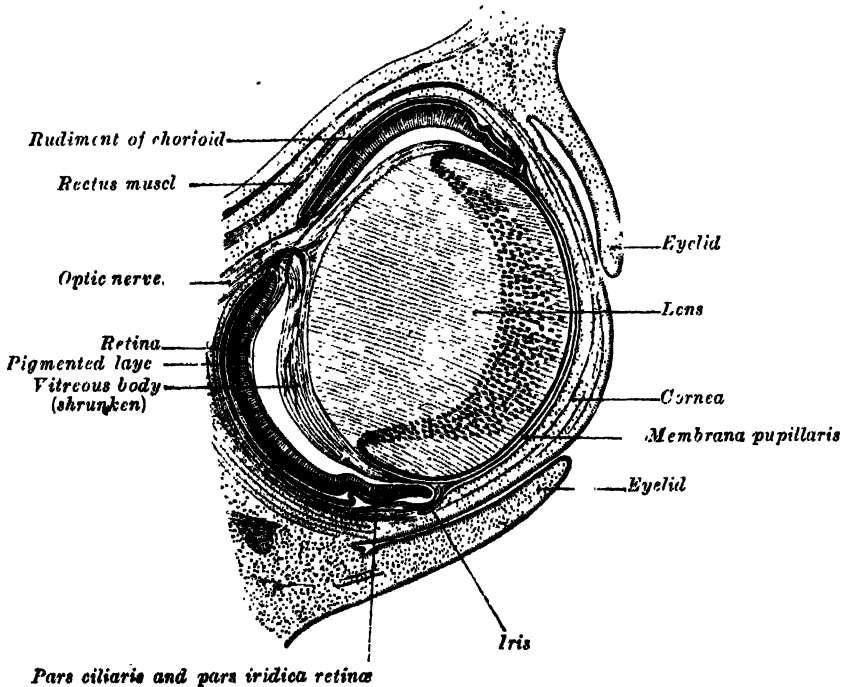
and form the pigmented layer of the retina; the pigment first appears in the cells near the edge of the cup. The cells of the inner stratum proliferate and form a

- FIG. 150.—Optic cup and chorioidal fissure seen from below, from a human embryo of about four weeks. (Kollmann.)



layer of considerable thickness from which the nervous elements and the sustentacular fibres of the retina, together with a portion of the vitreous body, are developed. In the portion of the cup which overlaps the lens the inner stratum is

- FIG. 151.—Section through the eye of an eighteen days' embryo rabbit. $\times 30$ (Kölliker.)

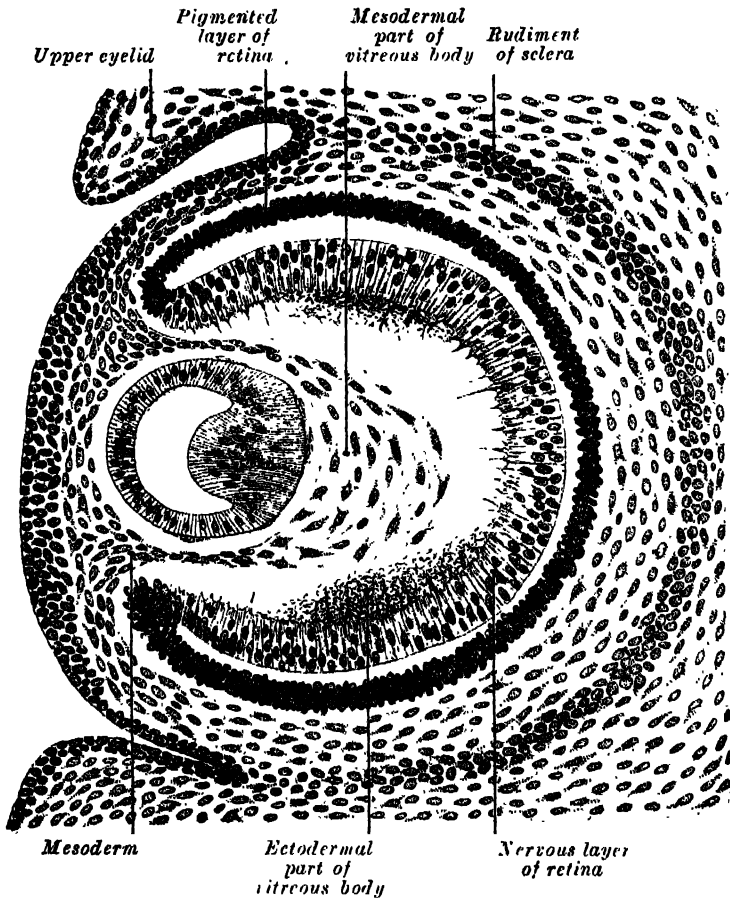


not differentiated into nervous elements, but persists as a layer of columnar cells which, together with the pigmented layer, form the *pars ciliaris* and *pars iridica retinae*.

The cells of the inner or retinal layer of the optic cup differentiate into spongioblasts and germinal cells, and the latter by their subdivisions give rise to neuroblasts. From the spongioblasts the sustentacular fibres of Müller, the outer and inner limiting membranes, together with the ground-work of the molecular layers of the retina, are formed. The neuroblasts become arranged to form the ganglionic and nuclear layers. The layer of rods and cones is first developed in the central part of the optic cup, and from there gradually extends towards the cup margin. All the layers of the retina are completed by the eighth month of fetal life.

The optic stalk is converted into the optic nerve by the obliteration of its cavity and the growth of nerve-fibres into it. Most of these fibres are centripetal, and

FIG. 152.—Sagittal section of the eye of a human embryo of six weeks. (Kollmann.)



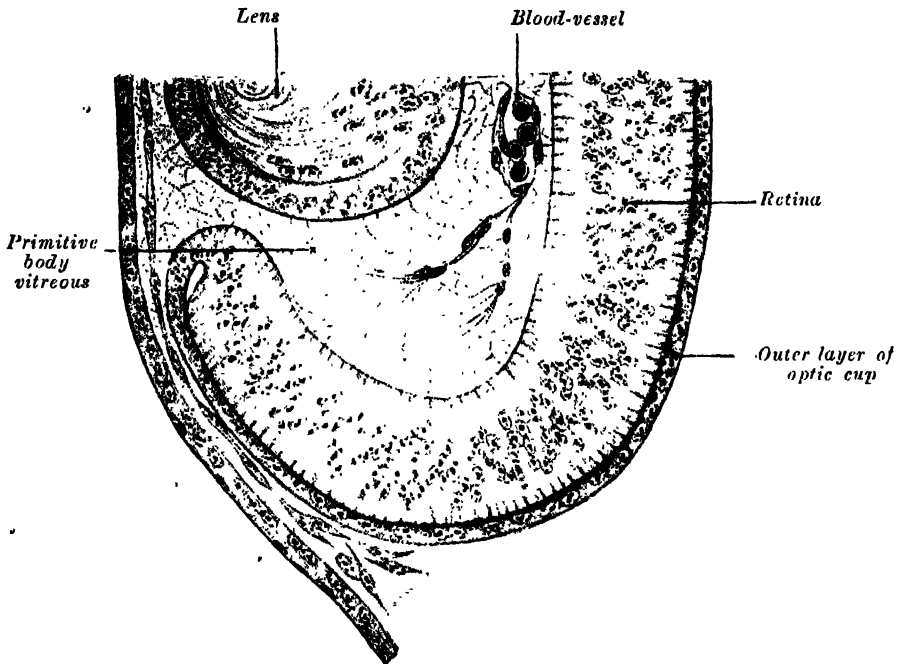
are the axons of the nerve-cells of the ganglionic layer of the retina, but a few are centrifugal and are derived from nerve-cells in the brain. The fibres of the optic nerve receive their medullary sheaths about the tenth week after birth. The optic chiasma is formed by the meeting and partial decussation of the fibres of the two optic nerves. Behind the chiasma the fibres are continued backwards as the optic tracts to the thalami and mesencephalon.

The crystalline lens is developed from the lens-vesicle, which recedes within the margin of the cup, and becomes separated from the overlying ectoderm by mesoderm. The cells forming the posterior wall of the vesicle lengthen and are converted into the lens-fibres, which grow forward and fill up the cavity of the vesicle (fig. 151). The cells forming the anterior wall retain their cellular character, and form the epithelium on the anterior surface of the fully developed lens. By the second month the lens is invested by a vascular mesodermal capsule, the *capsula vasculosa lentis*, the anterior part of which, covering the front of the lens, is named

the *pupillary membrane*; the blood-vessels supplying the posterior part of this capsule are derived from the hyaloid artery; those for the anterior part from the anterior ciliary arteries. By the sixth month all the vessels of the capsule are atrophied except the hyaloid artery, which disappears during the ninth month of fetal life; after birth the position of this artery is indicated by the hyaloid canal, which reaches from the optic disc to the posterior surface of the lens. With the loss of its blood-vessels the capsula vasculosa lentis disappears, but sometimes the pupillary membrane persists at birth, giving rise to the condition termed *congenital atresia of the pupil*.

The vitreous body is developed between the lens and the optic cup. The lens-rudiment and the optic vesicle are at first in contact with each other, but after the closure of the lens-vesicle and the formation of the optic cup the former is withdrawn from the retinal layer of the cup; the two, however, remain connected by a network

FIG. 153.—Section of the developing eye of a trout. (Szily.)



of delicate protoplasmic processes. This network, derived partly from the cells of the lens and partly from those of the retinal layer of the cup, constitutes the primitive vitreous body (figs. 152, 153). At first these protoplasmic processes spring from the whole of the retinal layer of the cup, but later are limited to the ciliary region, where by a process of condensation they appear to form the zonula ciliaris. The mesoderm which enters the cup through the chorioidal fissure and around the equator of the lens becomes intimately united with this reticular tissue, and contributes to form the vitreous body, which is therefore derived partly from the ectoderm and partly from the mesoderm.

The anterior chamber of the eye appears as a cleft in that part of the mesoderm which intervenes between the lens and the ectoderm. The layer of mesoderm in front of the cleft forms the substantia propria of the cornea, that behind the cleft the stroma of the iris and the pupillary membrane. The fibres of the Ciliaris muscle are derived from the mesoderm, but those of the Sphincter and Dilatator pupillæ are of ectodermal origin, being developed from the cells of the pupillary part of the optic cup.

The sclera and chorioid are derived from the mesoderm surrounding the optic cup.

The eyelids are formed as small cutaneous folds (figs. 149, 150). About the middle of the third month their edges come together and unite in front of the cornea; they remain united until about the end of the sixth month.

The lacrimal sac and nasolacrimal duct result from a thickening of the ectoderm in the groove (*naso-optic furrow*) between the lateral nasal and maxillary processes. This thickening forms a solid cord of cells which sinks into the mesoderm; during the third month the central cells of the cord break down, and a lumen, the nasolacrimal duct, is established. The lacrimal ducts arise as buds from the upper part of the cord of cells and secondarily establish openings (*puncta lacrimalia*) on the margins of the lids. The epithelium of the cornea and conjunctiva, and that which lines the ducts and alveoli of the lacrimal gland, is of ectodermal origin, as are also the eyelashes and the lining cells of the glands which open on the margins of the lids.

FIG. 154.—Section through the head of a human embryo, about twelve days old, in the region of the hind-brain. (Kollmann.)

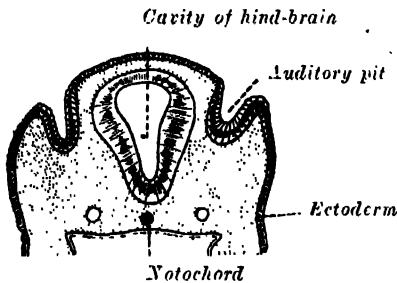


FIG. 155.—Section through the hind-brain and auditory vesicles of an embryo more advanced than that of fig. 154. (After His.)

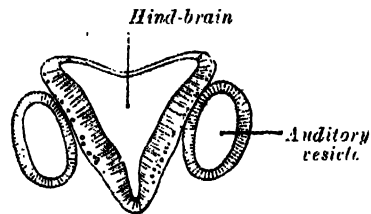


FIG. 156.—Left auditory vesicle of a human embryo of four weeks, seen from the outer surface. (W. His, jun.)

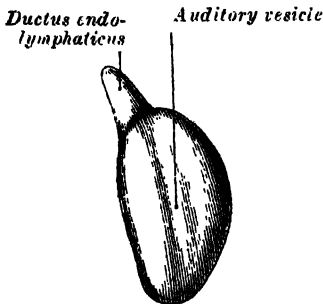
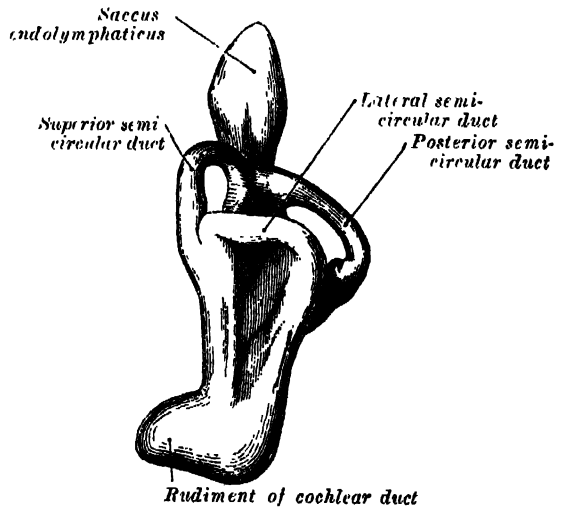


FIG. 157.—Left auditory vesicle of a human embryo of five weeks, seen from the outer surface. (W. His, jun.)

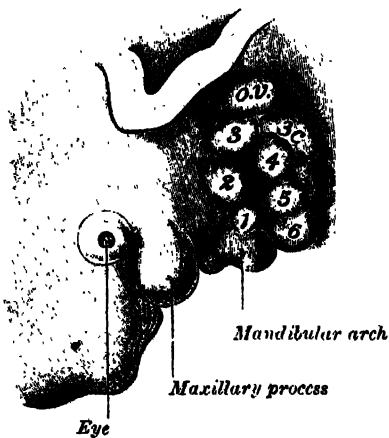


The ear.—The first rudiment of the internal ear appears shortly after that of the eye, in the form of a patch of thickened ectoderm, the *auditory plate*, over the region of the hind-brain. The auditory plate is invaginated and converted into the *auditory pit* (fig. 154). The mouth of the pit is then closed, and thus a shut sac, the *auditory vesicle* or *otocyst*, is formed (fig. 155); from it the epithelial lining of the membranous labyrinth is derived. The vesicle assumes a flask-shape, and the neck of the flask is obliterated (fig. 156). From the vesicle certain diverticula are given off which form the various parts of the membranous labyrinth. One from the middle part forms the ductus and saccus endolymphaticus. A second, from the anterior end, elongates, and forms the coiled tube of the cochlear duct, the proximal or vestibular extremity of which is subsequently constricted to form the

canalis reuniens. Three others appear as disc-like evaginations on the surface of the vesicle; the central parts of the walls of the discs coalesce and disappear, while the peripheral portions persist to form the semicircular ducts; of these the superior is the first, and the lateral the last, to be completed (fig. 157). The central part of the vesicle represents the membranous vestibule, and is subdivided by a constriction into a smaller ventral part, the saccule, and a larger dorsal and posterior part, the utricle (fig. 158). This subdivision is effected by a fold which extends deeply into the proximal part of the ductus endolymphaticus, with the result that the utricle and saccule ultimately communicate with each other by means of a Y-shaped canal. The saccule opens into the cochlear duct, through the canalis reuniens, and the semicircular ducts communicate with the utricle.

The mesoderm surrounding the various parts of the epithelial labyrinth is converted into a cartilaginous ear-capsule, and this is finally ossified to form the bony labyrinth. The portion of the capsule which envelopes the semicircular canals chondrifies before that which surrounds the cochlea. For a time the cartilaginous capsule is incomplete, and the cochlear, vestibular, and genicular ganglia are situated in the gap between its canalicular and cochlear parts. These ganglia are soon covered by an outgrowth of cartilage and at the same time the facial nerve is bridged by a growth of cartilage from the cochlear to the canalicular parts of the capsule. Between the cartilaginous capsule and the epithelial wall of the labyrinth a stratum of embryonic connective tissue is established, and in it the perilymphatic spaces are developed. Streeter* states that the rudiment of the vestibular perilymphatic space, or *periotic cistern* as he suggests this space should be named, can be seen in an embryo of from 30 to 40 mm. in length, in the reticulum between the saccule and the fenestra vestibuli. The scala tympani is next developed, and begins opposite the fenestra cochleæ. The scala vestibuli, the last to appear, is developed as an extension downwards of the vestibular perilymphatic space. The two scalæ gradually extend along the ductus cochlearis and when they reach the tip of the duct, a free opening is developed between them, and this represents the helicotrema.

FIG. 159.—Tubercles from which the different parts of the auricula are developed. (His.)

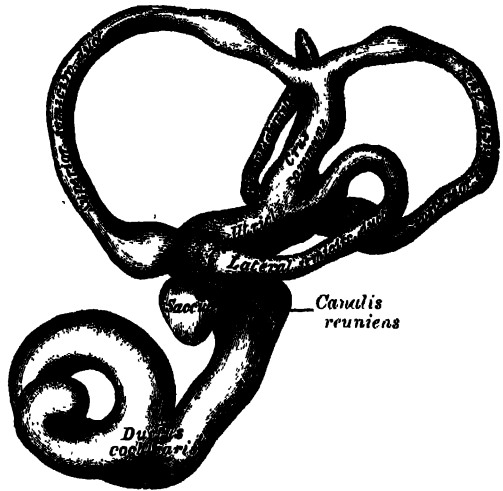


- 1, 2. Tubercles on mandibular arch. 3. Tubercle above groove. 3, c. Prolongation of 3 downwards. 4, 5, 6. Tubercles on hyoid arch. o.v. Auditory vesicle.

The modiolus and osseous spiral lamina of the cochlea are not preformed in cartilage but are ossified directly from connective tissue.

The auditory tube and tympanic cavity were formerly regarded as being derived from the first pharyngeal pouch, but J. Ernest Frazer† has recently pointed out

FIG. 158.—Left membranous labyrinth of a human embryo of 30 mm. (From model by W. His, jun.)



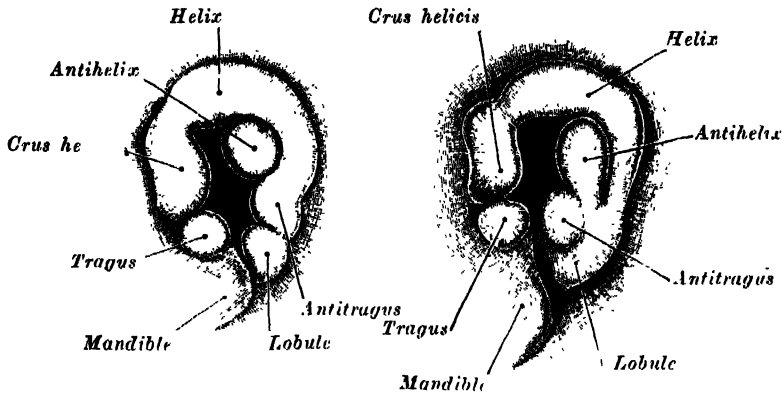
These ganglia are soon covered by an outgrowth of cartilage and at the same time the facial nerve is bridged by a growth of cartilage from the cochlear to the canalicular parts of the capsule. Between the cartilaginous capsule and the epithelial wall of the labyrinth a stratum of embryonic connective tissue is established, and in it the perilymphatic spaces are developed. Streeter* states that the rudiment of the vestibular perilymphatic space, or *periotic cistern* as he suggests this space should be named, can be seen in an embryo of from 30 to 40 mm. in length, in the reticulum between the saccule and the fenestra vestibuli. The scala tympani is next developed, and begins opposite the fenestra cochleæ. The scala vestibuli, the last to appear, is developed as an extension downwards of the vestibular perilymphatic space. The two scalæ gradually extend along the ductus cochlearis and when they reach the tip of the duct, a free opening is developed between them, and this represents the helicotrema.

* *American Journal of Anatomy*, vol. xxi.

† *Journal of Anatomy and Physiology*, vol. xlviii.

that they are developed from a recess, the *tubotympanic recess*, between the first and third visceral arches, the floor of the recess consisting of the first and second arches and the first and second pharyngeal pouches. By the forward growth of the third arch the inner part of the recess is narrowed to form the tubal region and the inner part of the second arch is excluded from this portion of the floor. The outer part of the recess is subsequently developed into the tympanic cavity,

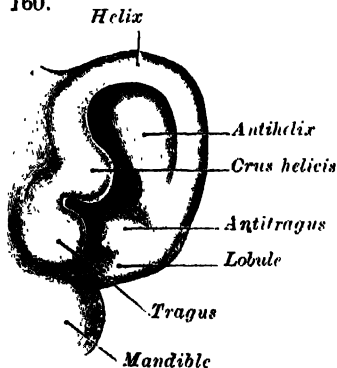
FIG. 160.—Left auriculæ of human embryos estimated to be thirty-five and thirty-eight days old respectively. (After His.)



and the floor of this part forms the outer wall of the tympanic cavity up to about the level of the chorda tympani nerve. From this it will be seen that the outer wall of the tympanic cavity 'has both first and second arch elements in it, the share taken by the first arch being limited to the part in front of the handle of the malleus. The area of the second arch includes the outer wall behind this, and turns on to the back wall to take in the tympanohyal region.' During the sixth or seventh month the tympanic antrum appears as an upward and backward expansion of the tympanic cavity.

With regard to the exact mode of development of the ossicles of the middle ear there is some difference of opinion. The view generally held is that the *incus*

FIG. 161.—Auricula in a more advanced stage of development than those represented in fig. 160.



and *malleus* are developed from the dorsal end of the mandibular (Meckel's) cartilage (fig. 116) and the *stapes* from the dorsal median portion of the second arch. The malleus, with the exception of its anterior process, is ossified from a single centre which appears near the neck of the bone; the anterior process is ossified separately in membrane and joins the main part of the bone about the sixth month of foetal life. The incus is ossified from one centre which appears in the upper part of its long crus and ultimately extends into its lenticular process. The stapes first appears as a ring (annulus stapedis) encircling a small vessel, the stapedia artery, which subsequently undergoes atrophy; the stapes is ossified from a single centre which appears in its base.

The external acoustic meatus is developed from the first branchial or outer pharyngeal groove. The lower part of this groove extends inwards as a funnel-shaped tube (primary meatus) from which the cartilaginous portion and a small part of the roof of the osseous portion of the meatus are developed. From the lower part of the funnel-shaped tube an epithelial lamina (*meatal plate*) extends downwards and inwards along the floor of the tubotympanic recess; by the splitting of this lamina the inner part of the meatus (secondary meatus) is produced, while the inner portion of the lamina forms the cutaneous stratum of the tympanic membrane. The

fibrous stratum of the tympanic membrane is formed from the mesoderm which extends between the meatal plate and the entoderm of the floor of the tubotympanic recess.

The auricula or pinna is developed by the gradual differentiation of six tubercles (fig. 159) which appear around the margin of the first branchial groove. Two tubercles appear on the posterior edge of the mandibular arch; these represent the rudiments of the tragus and crus helix. Three are found on the hyoid arch, and indicate, from below upwards, the lobule, antitragus, and antihelix. One arises dorsal to the first branchial groove, and grows downwards behind the antitragus and antihelix; from it and its downward prolongation the upper part of the helix and the cauda helix are developed (figs. 160, 161). Some observers, however, maintain that the lowest tubercle on the hyoid arch becomes the antitragus, and that the lobule is developed later as an independent formation. The rudiment of the *acoustic nerve* appears about the end of the third week as the acoustic ganglion which is closely applied to the cephalic edge of the auditory vesicle. Whether the cells of this ganglion are derived from the ectoderm adjoining the auditory vesicle, or have migrated from the wall of the neural tube, is as yet undetermined. The acoustic ganglion divides into the vestibular ganglion and the spiral ganglion of the cochlea. Their nerve-cells are bipolar, each sending a proximal fibre into the neural tube, and a distal fibre to the epithelial cells of the auditory vesicle.

DEVELOPMENT OF THE VASCULAR SYSTEM

Blood-corpuscles and blood-vessels first make their appearance between the entoderm and the mesoderm of the yolk-sac in what His named the *angioblast*.* Here the cells become arranged into solid strands or cords, and these join to form a close-meshed network, the *area vasculosa*, which covers the entire yolk-sac. The peripheral cells of these strands become flattened and joined to each other by their edges to form the endothelium of the walls of the primitive blood-vessels. Fluid collects within the strands and converts them into tubes, and the more centrally situated cells of the cell-cords are thus pushed to the sides of the vessels and appear as masses of loosely-arranged cells projecting towards the lumen of the tube. These masses are termed *blood-islands* (figs. 162, 163); their cells are detached to form the primary blood-corpuscles (*mesamœboids* of Minot). The earliest blood-vessels, therefore, are formed at several separate centres; from the walls of these vessels buds grow out,

FIG. 162.—Section through the vascular area to show differentiation of primitive vascular cells. (Diagrammatic.)

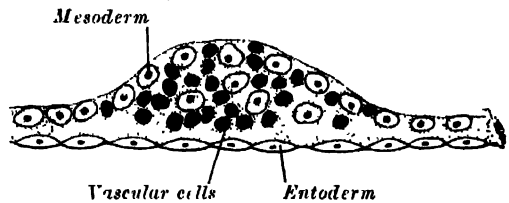
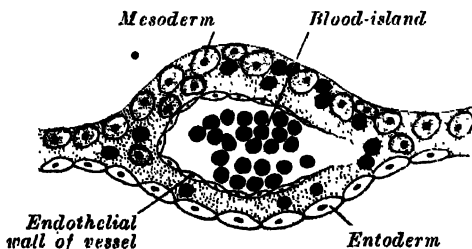


FIG. 163.—Section through a developing blood-vessel. (Diagrammatic.)



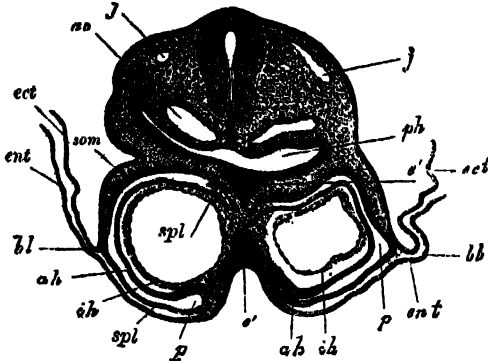
The red and the colourless corpuscles of the blood are all derived from the *mesamœboids*. The earliest blood-corpuscles are thus all nucleated; they are

become vascularised and converted into new vessels, and join with those of neighbouring areas to form a close meshwork. It is uncertain whether the vessels within the body of the embryo are extensions from this network (His) or whether they are of new formation. Most observers agree, however, that, after the aortæ have appeared, no other independent vessels are laid down, i.e. all new vessels are derived from pre-existing ones.

* Recent observations show that blood-islands and blood-vessels appear in the body-stalk and chorion independently of, and previous to, those of the yolk-sac. (Consult an article "On the earliest blood-vessels in Man" by J. L. Bremer in the *Anatomical Record*, vol. viii. Feb. 1914.)

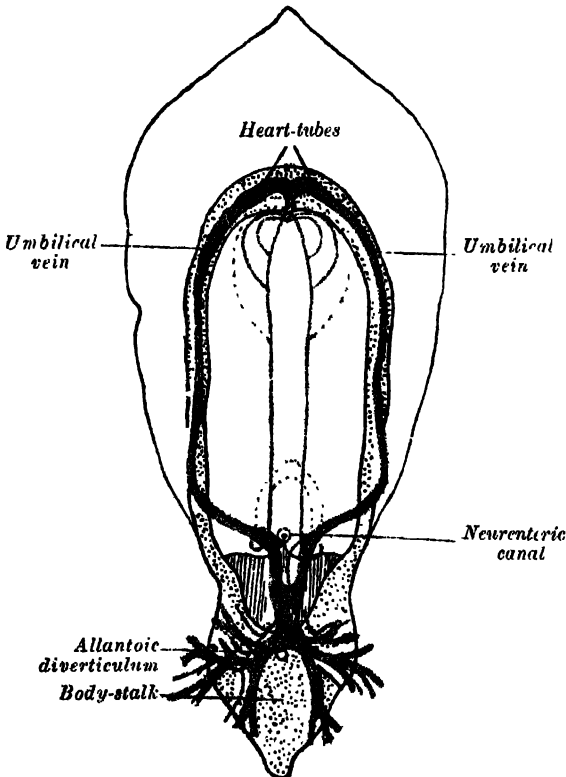
also capable of subdivision and of executing amoeboid movements. Some mesamœboids acquire colouring matter (hæmoglobin); their nuclei disintegrate and are extruded, and the non-nucleated red corpuscles or erythrocytes result. Other mesamœboid cells retain their nuclei; some remain in the blood as the leucocytes; others wander out into the tissues, particularly into the liver, lymphoid tissues, and marrow of the bones, where they form specialised collections from which the corpuscles of the blood are regenerated. From the mesamœboid cells five chief forms are derived: (1) erythrocytes, (2) lymphocytes, (3) finely granular or neutrophil leucocytes, (4) coarsely granular or eosinophil leucocytes, (5) degenerating or basophil leucocytes.

FIG. 164.—Transverse section through the region of the heart in a rabbit embryo of nine days. $\times 80$. (Kölliker.)



ah. Outer wall of heart. ao. Aorta. bl. Blastomeres. a. Septum between heart-tubes. ect. Ectoderm. ent. Entoderm. ih. Endothelial lining of heart. j, j. Jugular veins. p. Pericardium. ph. Pharynx. som. Somatopleure. spl. Splanchnopleure.

FIG. 165.—Diagram of the vascular channels in a human embryo of the second week. (After Eternod.) (From Quain's Elements of Anatomy, vol. i., Embryology.)

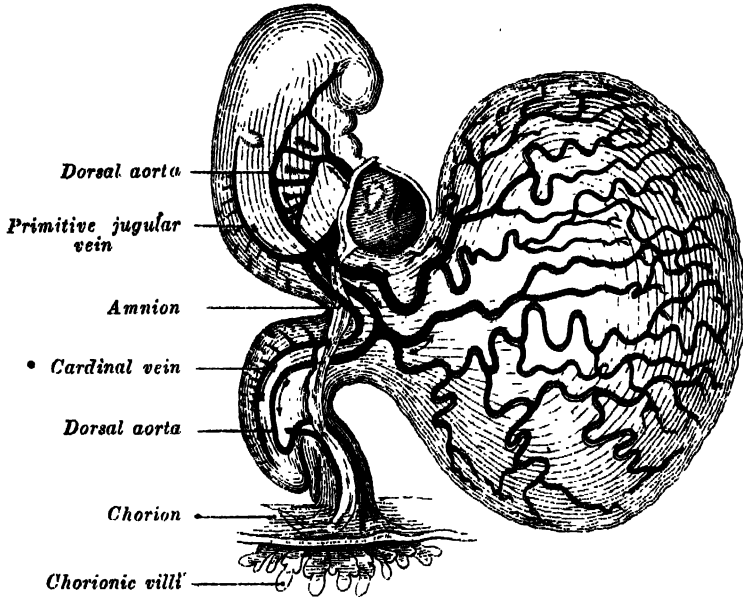


The red lines are the dorsal aortæ continued into the umbilical arteries. The red dotted lines are the ventral aortæ, and the blue dotted lines the vitelline veins.

yolk-sac (His), or are developed from vascular cells *in situ*, and subsequently establish connexions with those of the yolk-sac.

The first rudiment of the heart appears in the form of a pair of tubular vessels (primitive aortæ) which are developed in the splanchnopleure of the pericardial area (fig. 164). These two vessels run backwards, one on either side of the notochord,

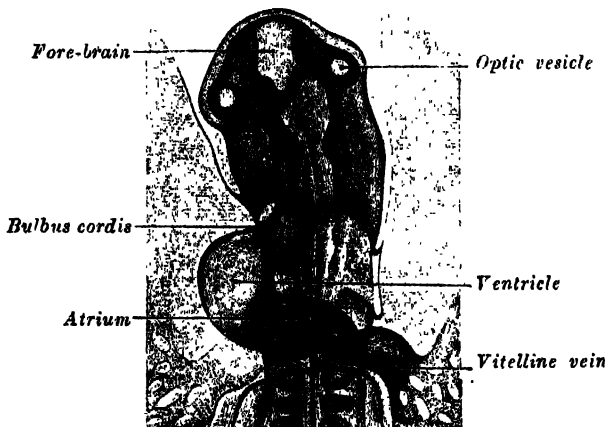
FIG. 166.—Human embryo about fourteen days old with yolk-sac. (After His.)



and pass into the body-stalk along which they are carried as the umbilical arteries to the chorion.

By the forward growth and flexure of the head the pericardial area and the anterior portions of the primitive aortæ are folded under the head and come to lie on the ventral aspect of the fore-gut, and each vessel now consists of a ventral and a dorsal part united by an arch; these three parts are named respectively the

FIG. 167.—Head of a chick embryo about thirty-eight hours old, viewed from the ventral surface. $\times 26$. (From Duval's Atlas d'Embryologie.)



ventral aorta, the dorsal aorta, and the first aortic arch. The first aortic arches pass through the mandibular arches, and behind them five additional pairs subsequently develop, so that altogether six pairs of aortic arches are formed.

In the pericardial region the two primitive aortæ, which from the first lie close together, come into contact and the partition between them disappears, and thus a single tubular heart is formed (fig. 167); from the cephalic end of the heart the ventral aortæ arise and into its caudal end the umbilical and vitelline veins pour their contents.

FIG. 168.—Diagram to illustrate the simple tubular condition of the heart. From Ecker-Ziegler model.)

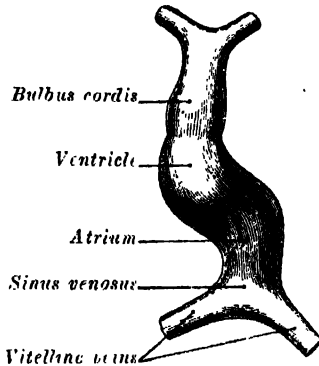
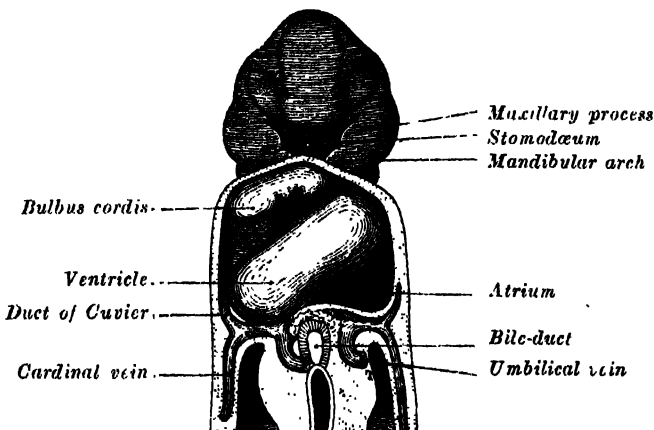


FIG. 169.—Heart of a human embryo of about fourteen days. (From a model by His.)



Eternod * described the circulation in a human embryo which measured 1.3 mm. in length and was devoid of mesodermal somites (fig. 165). The rudiment of the heart was situated immediately below the fore-gut and consisted of a short stem. It gave off two vessels, the primitive aortæ, which ran backwards, one on either side of the rudiment of the notochord, and then passed into the body-stalk, along which they were carried to the chorion. From the chorionic villi the blood was returned by a pair of umbilical veins which united in the body-stalk to form a single vein (vena umbilicalis impar); on reaching the embryo this vein divided into two

FIG. 170.—Heart of a human embryo of about fifteen days. (Reconstruction by His.)

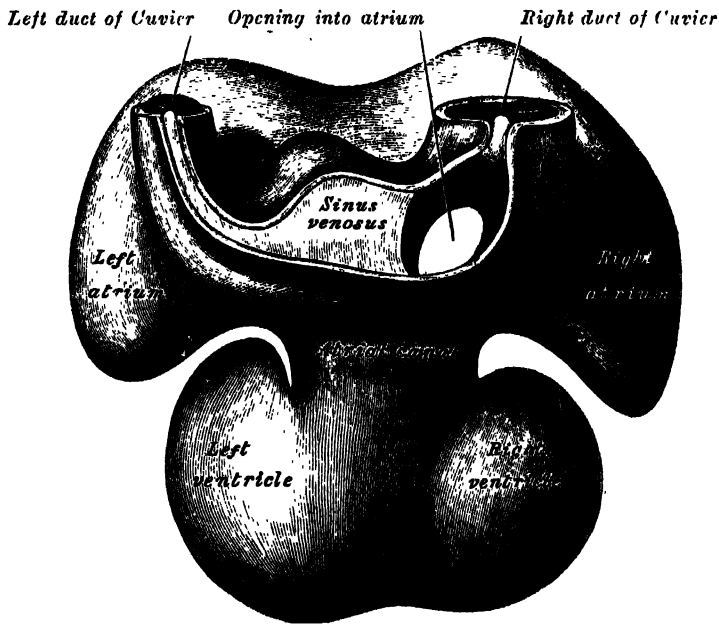


which encircled the mouth of the yolk-sac and opened into the heart. At the junction of the yolk-sac and body-stalk each vein was joined by a transitory vitelline vein from the vascular plexus of the yolk-sac.

The transitory vitelline veins are replaced by the true vitelline veins which return the blood from the yolk-sac, and enter the embryo through the anterior wall of the

umbilical orifice (figs. 166, 167). They then traverse the septum transversum, a band of mesoderm which lies between the pericardium and the yolk-sac; in this septum each vitelline vein unites with the corresponding umbilical vein to form the *common vitello-umbilical vein* which opens into the caudal end (sinus venosus) of the tubular heart. The vitello-umbilical veins are soon joined by a pair of anterior cardinal and primitive jugular veins from the head, and a little later each anterior cardinal vein is joined by a posterior cardinal vein from the trunk and limbs and the short trunk (duct of Cuvier) formed by the union of these two veins opens into the corresponding vitello-intestinal vein. The sinus venosus expands in a transverse direction and incorporates the adjoining parts of the vitello-umbilical veins which come to form the right and left horns of the sinus; into either horn of the sinus the three venous trunks, viz. the vitelline vein, the umbilical vein and the duct of Cuvier, open. The liver is developed in the septum transversum, and in the course of its develop-

FIG. 171.—Dorsal surface of the heart of a human embryo of thirty-five days.
(From model by His.)



ment the vitelline and umbilical veins undergo important transformations which will be explained later (page 139).

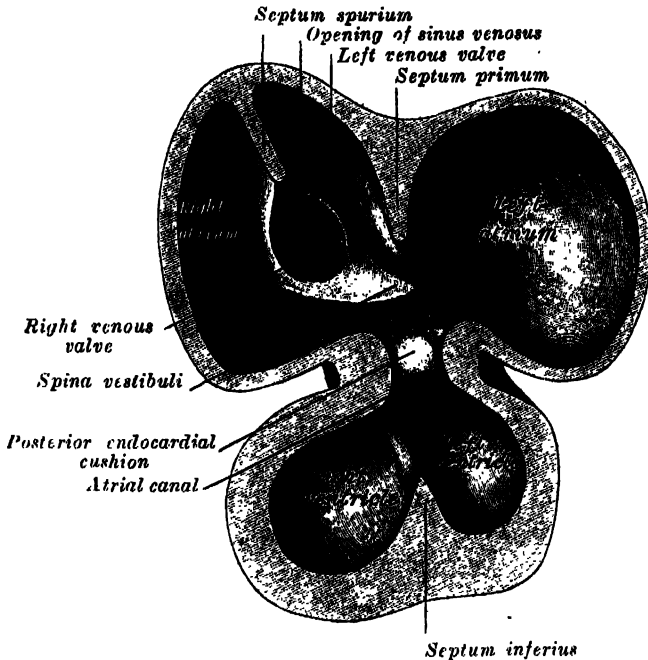
With the atrophy of the yolk-sac the vitelline circulation diminishes and ultimately ceases, and an increasing amount of blood is carried through the umbilical arteries to the villi of the chorion. Subsequently, as the non-placental chorionic villi atrophy, their vessels disappear; and then the umbilical arteries convey the whole of the blood from the embryo to the placenta, whence it is returned to the embryo by the umbilical veins.

Further development of the Heart.—The simple tubular heart, already described (page 111), elongates and bends so as to form an S-shaped loop, the anterior part convex ventrally and to the right, and the posterior, dorsally and to the left (fig. 169). The intermediate portion arches transversely from left to right, and then turns sharply forward into the anterior part of the loop. Slight constrictions make their appearance in the tube and divide it from behind forwards into five parts, viz.: (1) the *sinus venosus*; (2) the *atrium*; (3) the *ventricle*; (4) the *bulbus cordis*, and (5) the *truncus arteriosus* (fig. 169). The constriction between the atrium and ventricle constitutes the *atrial canal*, and indicates the site of the future atrio-ventricular valves.

The sinus venosus is situated in the septum transversum behind the atrium, and opens into the latter by a median aperture. The sinus is at first placed trans-

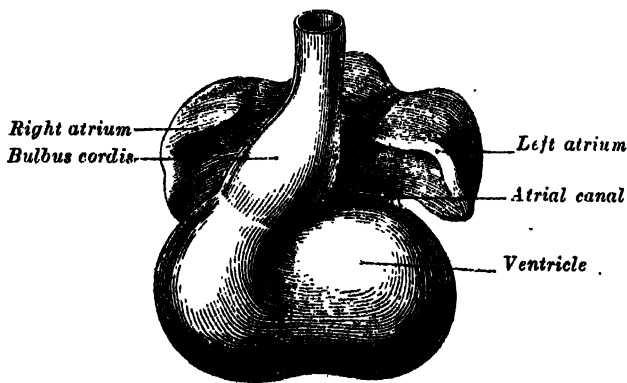
versely but soon assumes an oblique position and a crescentic shape (fig. 171); its right half or horn increases in size more rapidly than its left, and the sinus opens into the right portion of the atrium. The right horn of the sinus is ultimately

FIG. 172.—Interior of the dorsal half of the heart of a human embryo of about thirty (From a model by His.)



incorporated with and forms a part of the right atrium, the line of union between it and the auricula being indicated in the interior of the adult atrium by a vertical crest, the *crista terminalis* of His. The left horn, which ultimately receives only the left duct of Cuvier, persists as the coronary sinus (fig. 171). The vitelline and umbilical veins are later replaced by a single vessel, the inferior vena cava, and the

FIG. 173.—Heart showing expansion of the atria. (From Ecker-Ziegler model.)

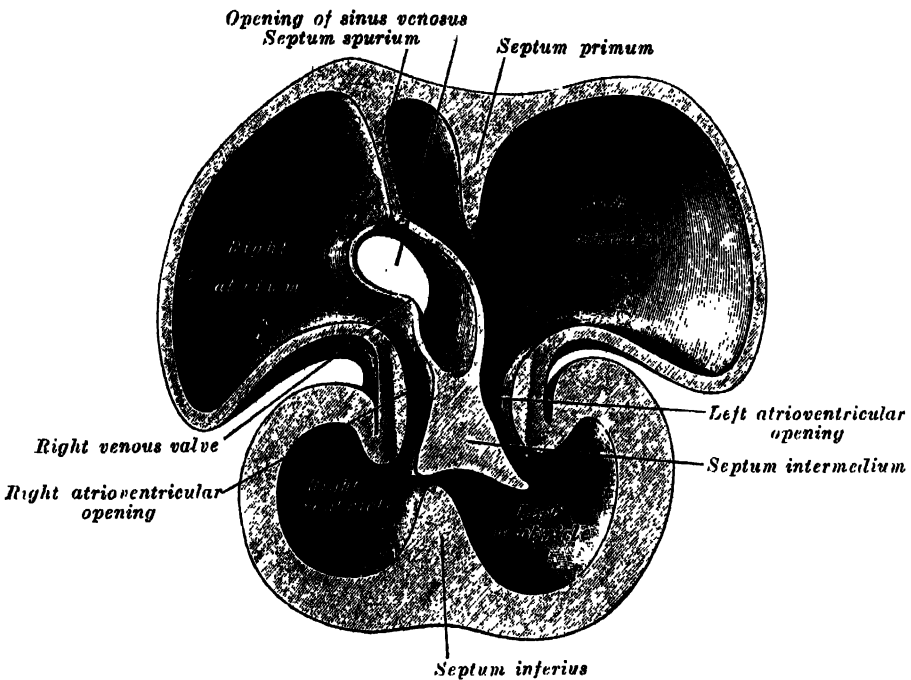


three veins (inferior vena cava and right and left ducts of Cuvier) open into the dorsal part of the atrium by a common slit-like aperture (fig. 172). The upper part of this aperture represents the opening of the permanent superior vena cava, the lower that of the inferior vena cava, and the intermediate part the orifice of the coronary sinus. The slit-like aperture lies obliquely, and is guarded by two valves,

the *right* and *left venous valves*; above the opening these unite with each other and are continuous with a fold named the *septum spurium*; below the opening they fuse to form a triangular thickening—the *spina vestibuli*. The right venous valve is retained; its cephalic portion, together with the *septum spurium*, forms the *crista terminalis* already mentioned. A small septum, the *sinus septum*, grows from the posterior wall of the sinus venosus to fuse with the right venous valve and divide the rest of it into two parts—an upper, the valve of the inferior vena cava, and a lower, the valve of the coronary sinus. The upper and middle thirds of the left venous valve disappear; the lower third is continued into the *spina vestibuli*, and later fuses with the *septum secundum* of the atria and takes part in the formation of the *limbus fossæ ovalis*.

The atrial canal is at first a short straight tube connecting the atrial with the ventricular portion of the heart, but its growth is relatively slow, and it becomes

FIG. 174.—Interior of the dorsal half of the heart of a human embryo of about thirty-five days. (From a model by His.)

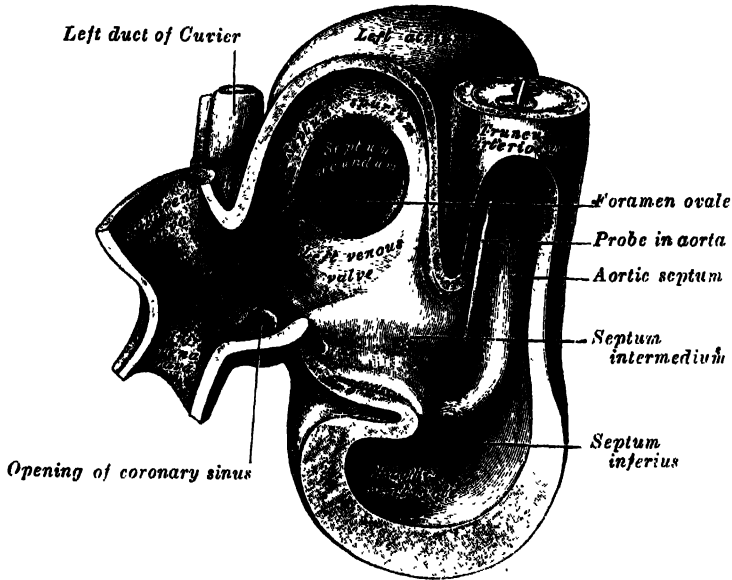


overlapped by the atria and ventricles so that its position on the surface of the heart is indicated only by an annular constriction (fig. 173). Its lumen is reduced to a transverse slit, and two thickenings, or *endocardial cushions* (fig. 172), appear, one on its dorsal, and the other on its ventral wall. These endocardial cushions project into the atrial canal, and, meeting in the middle line, unite to form the *septum intermedium* which divides the canal into two channels, the future right and left atrioventricular orifices.

The atrium grows rapidly, and expanding laterally, partially encircles the *bulbus cordis*; the latter comes to lie in a groove which is the first indication of a division into right and left atria. The cavity of the atrium is divided into right and left chambers by a septum, the *septum primum* (figs. 172, 174), which grows from the dorsal to the ventral wall of the cavity. For a time the atria communicate with each other by an opening, the *ostium primum* of Born, in front of the free margin of the *septum primum*. This opening is closed by the union of the *septum primum* with the *septum intermedium*, but before this occurs a new opening is developed in the upper part of the *septum primum*; this new opening is known as the *foramen ovale* (*ostium secundum* of Born) and persists until birth. A second septum, the *septum secundum* (fig. 175), crescentic in shape, grows from the upper

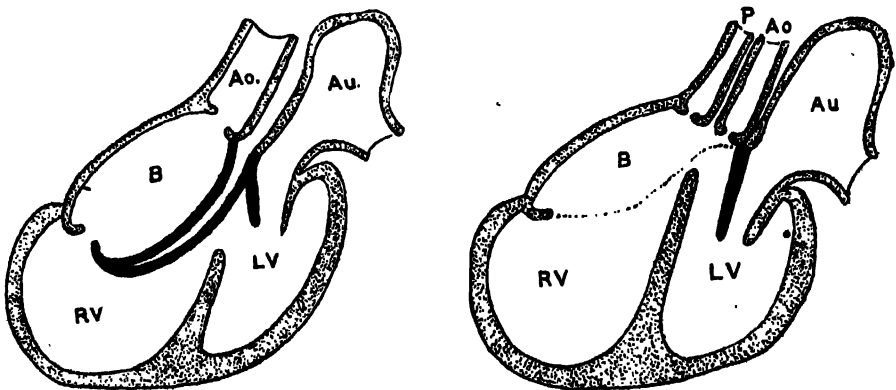
and dorsal wall of the atrium immediately to the right of the septum primum and foramen ovale. The horns of this crescentic septum secundum fuse with the ventral part of the septum primum, and the intervening free part of the septum

FIG. 175.—Heart of a human embryo of about thirty-five days, opened on right side.
(From a model by His.)



secundum overlaps the foramen ovale and septum primum; the dorsal part of the latter septum acts as a flap-like valve which allows the blood to flow from the right into the left atrium, but not in an opposite direction. After birth, the free edge of the septum secundum blends with the septum primum and the foramen ovale is closed; sometimes the fusion is incomplete and the upper part of the foramen

FIG. 176.—Diagrams to illustrate the transformation of the bulbus cordis. (Keith.)



Ao. Truncus arteriosus. Au. Atrium. B. Bulbus cordis. LV. Left ventricle.
P. Pulmonary artery. RV. Right ventricle.

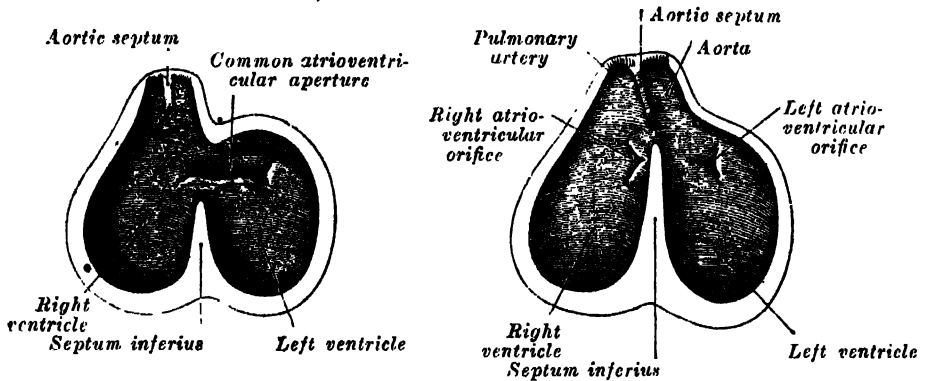
remains patent. In the adult heart the limbus fossæ ovalis denotes the free margin of the septum secundum.

Issuing from either lung is a pair of pulmonary veins which unite to form a single vein, and these in turn join with one another to form a common trunk which

opens into the left atrium. Subsequently the common trunk and the two veins forming it expand and form the vestibule or greater part of the left atrium, the expansion reaching as far as the orifices of the four veins which open separately into the adult left atrium.

The ventricle is divided by a septum, the *septum inferius* or *ventricular septum* (figs. 172, 174, 175), which grows upwards from the lower part of the ventricle, its position on the surface of the heart being indicated later by the interventricular

FIG. 177.—Diagrams to show the development of the septa of the aortic bulb and ventricles. (Born.)

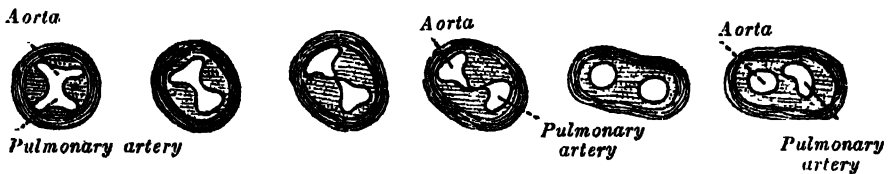


sulcus. Its dorsal part increases more rapidly than its ventral portion, and fuses with the dorsal part of the septum intermedium. Above its ventral portion there exists for a time an interventricular foramen (fig. 175), but this is ultimately closed by the fusion of the bulbar septum with the ventricular septum.

When the heart assumes its S-shaped form the bulbus cordis lies in front of and ventral to the ventricle. The adjacent walls of the bulbus cordis and ventricle approximate, fuse, and finally disappear, and the bulbus cordis now communicates freely with the right ventricle, while the junction of the bulbus with the truncus arteriosus is brought directly ventral, and applied, to the atrial canal. By the up-growth of the ventricular septum the bulbus cordis is in great measure separated from the left ventricle, but remains an integral part of the right ventricle, of which it forms the infundibulum (fig. 176).

The truncus arteriosus and bulbus cordis are divided by a septum (fig. 177) which makes its appearance in three portions. (1) Two distal ridge-like thickenings project into the lumen of the tube; these increase in size, and ultimately meet and fuse

FIG. 178.—Transverse sections through the aortic bulb to show the growth of the aortic septum. The lowest section is on the left, the highest on the right of the figure. (After His.)

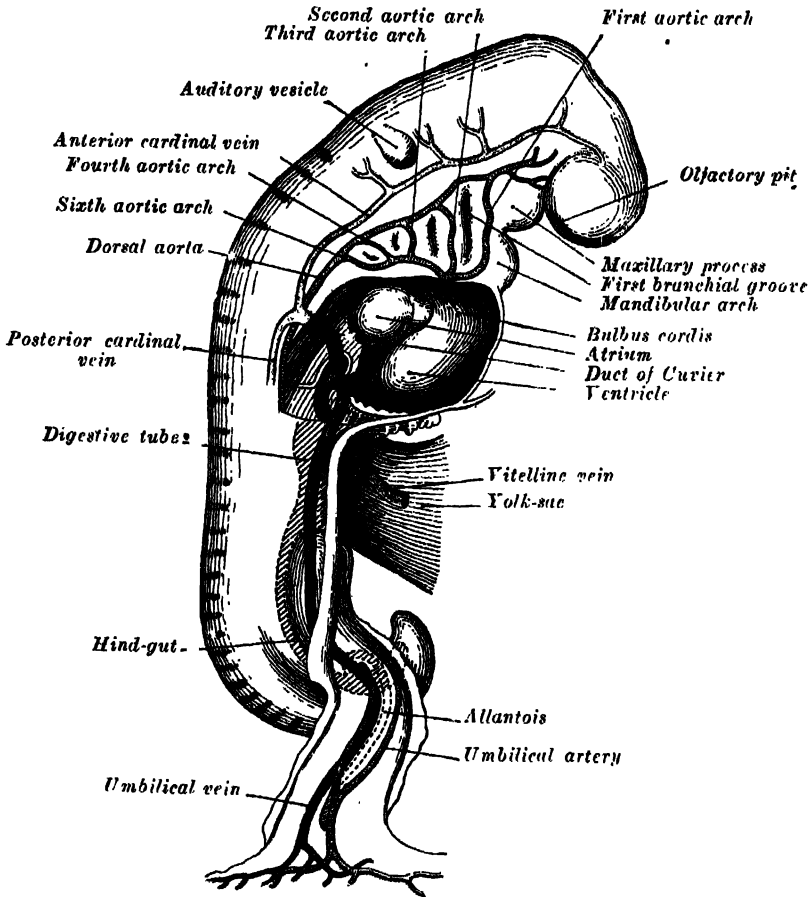


to form the aortic septum, which takes a spiral course towards the proximal end of the truncus arteriosus. It divides the distal part of the truncus into two vessels, the aorta and pulmonary artery, which lie side by side above, but near the heart, the pulmonary artery is in front of the aorta. (2) Four endocardial cushions appear in the proximal part of the truncus arteriosus in the region of the future semilunar valves; the manner in which these are related to the aortic septum is described below. (3) Two endocardial thickenings— anterior and posterior—develop in the bulbus cordis and unite to form a short bulbar septum; this joins above with the aortic septum and below with the ventricular septum. The bulbar septum grows down into the ventricle as an oblique partition, which ultimately

blends with the ventricular septum in such a way as to bring the bulbus cordis into communication with the pulmonary artery, and through the latter with the sixth pair of aortic arches; while the left ventricle is brought into continuity with the aorta, which communicates with the remaining aortic arches. The completed ventricular septum consists of a lower, muscular, and an upper, membranous, part; the former is developed from the septum inferius, the latter from the bulbar septum.

The valves of the heart.—The atrioventricular valves are developed in relation to the atrial canal. By the upward expansion of the bases of the ventricles the canal becomes invaginated into the ventricular cavities. The invaginated margin forms

FIG. 179.—Profile view of a human embryo estimated to be twenty or twenty-one days old. (After His.)

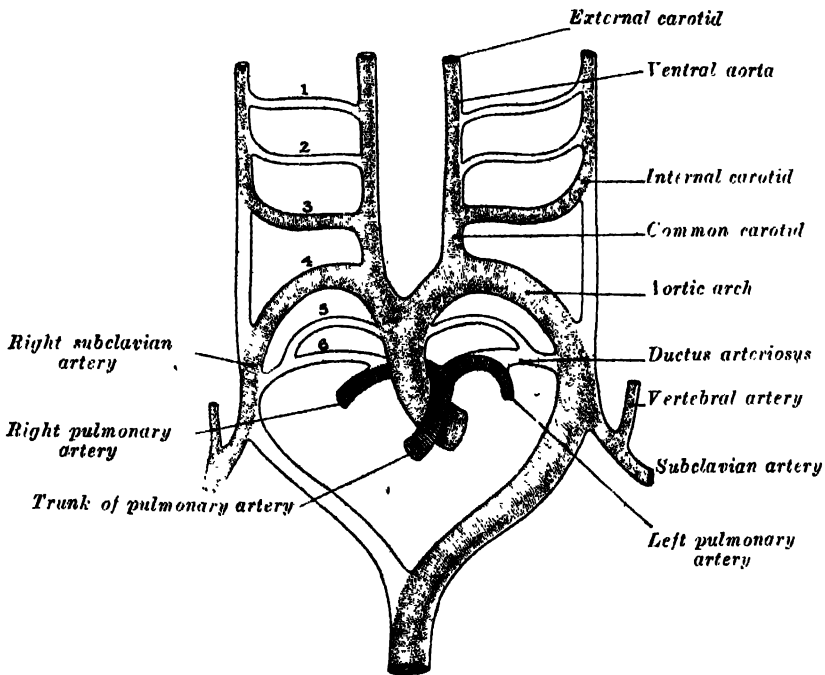


the rudiments of the lateral cusps of the atrioventricular valves; the medial or septal cusps of the valves are developed as downward prolongations of the septum intermedium (fig. 174). The aortic and pulmonary semilunar valves are formed from four endocardial thickenings—an anterior, a posterior, and two lateral—which appear at the proximal end of the truncus arteriosus. As the aortic septum grows downwards it divides each of the lateral thickenings into two, thus giving rise to six thickenings—the rudiments of the semilunar valves—three at the aortic and three at the pulmonary orifice (fig. 178).

Further development of the arteries.—Recent observations show that practically none of the main vessels of the adult arise as single trunks in the embryo. At the site of each vessel a capillary network forms, and by the enlargement of definite paths in this network the larger arteries and veins are developed. The branches of the main arteries are not always simple modifications of the vessels of the capillary network, but may arise as new outgrowths from the enlarged stem.

It has been seen (page 111) that each primitive aorta consists of a ventral and a dorsal part which are continuous through the first aortic arch. The dorsal aortæ at first run backwards separately on either side of the notochord, but in the third week they fuse from about the level of the fourth thoracic to that of the fourth lumbar segment to form a single trunk, the descending aorta. The first aortic arches run through the mandibular arches, and behind them five additional pairs are developed within the corresponding visceral arches; so that, in all, six pairs of aortic arches are formed (figs. 179, 180). The fifth arches are very transitory vessels connecting the truncus arteriosus with the dorsal ends of the sixth arches. The first and second arches pass between the ventral and dorsal aortæ, while the others arise at first by a common stem from the truncus arteriosus, but end separately in the dorsal aortæ. As the neck elongates, the ventral aortæ are drawn out, and the third and fourth arches arise directly from these vessels.

FIG. 180.—Scheme of the aortic arches and their transformations.
(Modified from Kollmann.)



In fishes the aortic arches persist and give off branches to the gills, in which the blood is oxygenated. In mammals some of the arteries remain as permanent structures, while others disappear or are obliterated (fig. 180).

The ventral aortæ.—These persist on both sides. The right ventral aorta forms, as far as the fourth aortic arch, the innominate artery, and beyond that arch the right common and external carotid arteries. The left gives rise to (a) the portion of the aortic arch between the origins of the innominate and left common carotid arteries; (b) the left common and external carotid arteries.

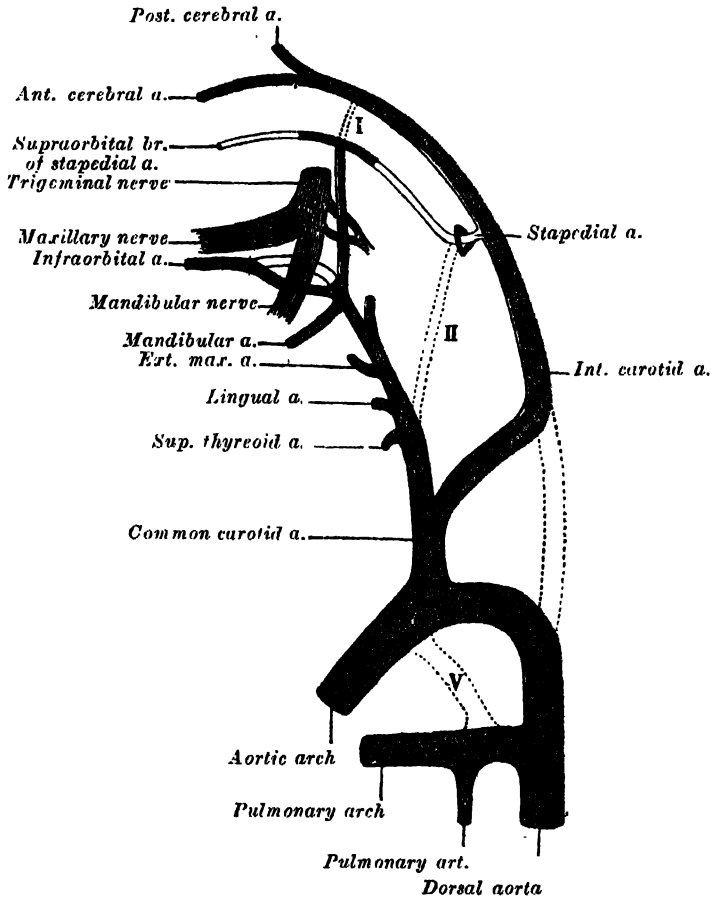
The aortic arches.—The first and second arches disappear, but the dorsal end of the second gives origin to the stapedia artery (fig. 181), a vessel which atrophies in man but persists in some mammals (e.g. the rat).

The stapedia artery passes through the ring of the stapes and divides into supra-orbital, infraorbital, and mandibular branches which follow the three divisions of the trigeminal nerve. The infraorbital and mandibular branches arise from a common stem, the terminal part of which anastomoses with the external carotid. On the obliteration of the stapedia artery this anastomosis enlarges and forms the internal maxillary artery, and the branches of the stapedia artery are now branches of this vessel. The common stem of the infraorbital and mandibular branches passes between the two

roots of the auriculotemporal nerve and becomes the middle meningeal artery; the original supraorbital branch of the stapedia is represented by the orbital twigs of the middle meningeal artery.

The third aortic arch constitutes the commencement of the internal carotid artery, and is therefore named the *carotid arch*. The fourth right arch forms the right subclavian as far as the origin of its internal mammary branch, while the fourth left arch constitutes the arch of the aorta between the origin of the left common

FIG. 181.—Diagram showing the origins of the main branches of the carotid arteries. (Founded on Tandler.) (From Quain's Elements of Anatomy, vol. i., Embryology, T. H. Bryce.)



carotid artery and the termination of the ductus arteriosus. The fifth arch disappears on both sides. The sixth right arch disappears; the sixth left arch gives off the pulmonary arteries and forms the ductus arteriosus; this duct remains pervious during foetal life, but is obliterated a few days after birth and forms the ligamentum arteriosum of the adult. His showed that in the early embryo the sixth arch on either side gives a branch to the corresponding lung, but later both pulmonary arteries take origin from the left arch.

The dorsal aortæ.—In front of the third aortic arches the dorsal aortæ persist and form the continuations of the internal carotid arteries; these arteries pass to the brain, and each divides into an anterior and a posterior branch, the former giving off the ophthalmic and the anterior and middle cerebral arteries, while the latter turns back and joins the cerebral part of the vertebral artery. Behind the third arch the right dorsal aorta disappears as far as the point where the two dorsal aortæ fuse to form the descending aorta. The part of the left dorsal aorta between the third and fourth arches disappears, while the remainder persists to form the descending

part of the arch of the aorta. A constriction, the *aortic isthmus*, is sometimes seen in the aorta between the origin of the left subclavian and the attachment of the ductus arteriosus.

Sometimes the right subclavian artery arises from the aortic arch distal to the origin of the left subclavian and passes upwards and to the right behind the trachea and œsophagus. This condition may be explained by the persistence of the right dorsal aorta and the obliteration of the fourth right arch.

In birds the fourth right arch forms the arch of the aorta; in reptiles the fourth arch persists on both sides and gives rise to the double aortic arch in these animals.

The heart originally lies on the ventral aspect of the pharynx, immediately caudal the stomodæum; with the elongation of the neck and the development of the lungs it recedes within the thorax, and, as a consequence, the anterior ventral aortæ are drawn out and the original position of the fourth and fifth arches is greatly modified. Thus, on the right side the fourth arch recedes to the root of the neck, while on the left side it is withdrawn within the thorax. The recurrent nerves originally pass to the larynx under the sixth pair of arches, and are therefore pulled backwards with the descent of these structures, so that in the adult the left nerve hooks round the ligamentum arteriosum; owing to the disappearance of the fifth and the sixth right arches the right nerve hooks round that immediately above them, i.e. the commencement of the subclavian artery.

The primitive dorsal aortæ give off ventral, dorsal, and lateral groups of segmental arteries.

The *ventral* segmental arteries, the first to be developed, are originally paired vessels, but, after the fusion of the dorsal aortæ, appear as unpaired trunks; they are distributed to the primitive digestive tube and to the wall of the yolk-sac. Three of them persist and constitute the coeliac, superior mesenteric, and inferior mesenteric arteries of the adult. As the viscera supplied by these three arteries descend into the abdomen, the vessels at the same time wander in a caudal direction; thus, the origin of the coeliac artery is transferred from the level of the seventh cervical to that of the twelfth thoracic segment, the superior mesenteric from the second thoracic to the first lumbar segment, and the inferior mesenteric from the twelfth thoracic to the third lumbar segment.

The *dorsal* segmental arteries are at first distributed to the neural tube, but later give off parietal branches to the body-wall; they persist in the thoracic and lumbar regions as the intercostal and lumbar arteries. From the seventh pair the entire left subclavian artery, the greater part of the right subclavian artery, and the proximal part of the vertebral artery are derived; the main part of the cervical portion of the vertebral artery is developed from a longitudinal anastomosis between the first seven dorsal segmental arteries. The second dorsal segmental arteries run alongside the hypoglossal nerves to the brain and are named the hypoglossal arteries. Each sends forwards a branch which forms the cerebral part of the vertebral artery and anastomoses with the posterior branch of the internal carotid artery; the cerebral portions of the two vertebrals unite on the ventral surface of the pons to form the basilar artery. The hypoglossal arteries atrophy, and then the cervical and cerebral parts of the vertebrals are connected by means of the first pair of segmental arteries.

The *lateral* segmental arteries supply, on either side, the mesonephros or Wolfian body and give branches to the testis (or ovary) and the suprarenal glands. One testicular (or ovarian) artery and three suprarenal arteries persist on either side. The inferior phrenic artery arises as a branch from the first, and the renal artery as a branch from the third suprarenal artery. Additional renal arteries are frequently present and may be looked on as branches of persistent lateral segmental arteries.

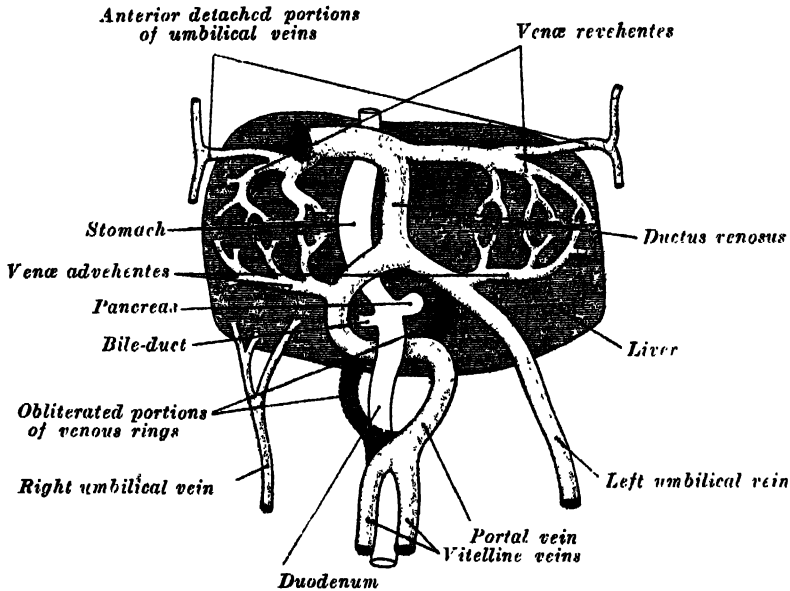
Recent observations show that several segmental arteries contribute branches to the upper limb-bud and form in it a free capillary anastomosis. Of these branches only one, viz. that derived from the seventh segmental artery, persists to form the subclavian artery. The subclavian artery is prolonged into the limb under the names of the axillary and brachial arteries, and these together constitute the arterial stem for the upper arm; the direct continuation of this stem in the forearm is the volar interosseous artery. A branch which accompanies the median nerve soon increases in size and forms the main vessel (median artery) of the forearm, while the volar interosseous diminishes. Later the radial and ulnar arteries are developed as branches of the brachial part of the stem and coincidently with their

enlargement the median artery recedes; occasionally it persists as a vessel of some size and accompanies the median nerve into the palm of the hand.

The primary arterial stem for the lower limb is formed by the inferior glutæal (sciatic) artery, which accompanies the sciatic nerve along the posterior aspect of the thigh to the back of the knee, whence it is continued as the peronæal artery. This arrangement persists in reptiles and amphibians. The external iliac artery and its continuation the femoral artery arise later from the common iliac. The femoral passes down the front and medial side of the thigh to the bend of the knee and joins the inferior glutæal artery. It quickly enlarges, and, coincidently with this, the lower part of the inferior glutæal atrophies. The anterior and posterior tibial arteries are branches of the main arterial stem.

Further Development of the Veins.—The principal veins of the embryo may be divided into two groups, visceral and parietal.

FIG. 182.—The liver, and the veins in connexion therewith, of a human embryo, twenty-four or twenty-five days old, as seen from the ventral surface. (After His.)



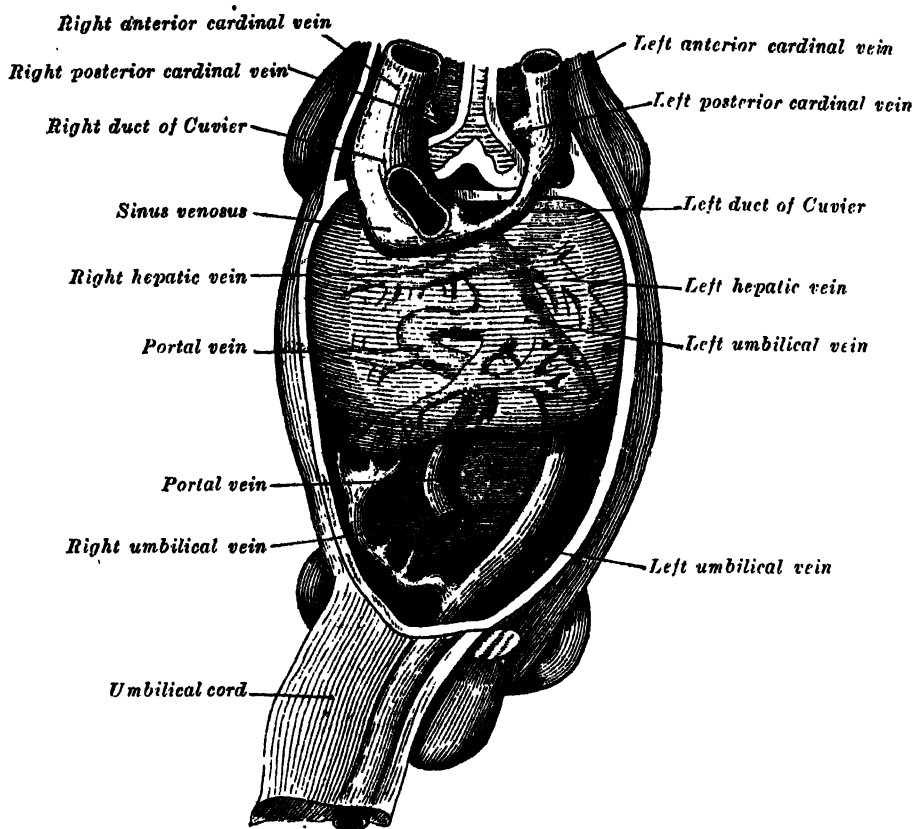
The *visceral veins* are the two vitelline veins bringing the blood from the yolk-sac, and the two umbilical veins returning the blood from the placenta; these four veins open close together into the sinus venosus.

The vitelline veins run upwards at first in front, and subsequently on either side, of the digestive tube. They unite on the ventral surface of the tube, and beyond this are connected to one another by two anastomotic branches, one on the dorsal and the other on the ventral aspect of the duodenal portion of the intestine, which is thus encircled by two venous rings (fig. 182); into the middle, or dorsal anastomosis the superior mesenteric vein opens. The portions of the veins above the upper ring become interrupted by the developing liver and broken up by it into a plexus of small capillary-like vessels termed *sinusoids* (Minot). The vessels conveying the blood to this plexus are named the *venæ advehentes*, and become the branches of the portal vein; while the vessels draining the plexus into the sinus venosus are termed the *venæ revehentes*, and form the future hepatic veins (figs. 182, 183). After a time the left vena revehens no longer communicates directly with the sinus venosus, but opens into the upper part of the right vena revehens (right hepatic vein). The persistent part of the upper venous ring, above the opening of the superior mesenteric vein, forms the trunk of the portal vein.

The two umbilical veins fuse to form a single trunk, the *vena umbilicalis impar*, in the umbilical cord; this trunk divides within the embryo into the right and left umbilical veins which pass forwards to the sinus venosus in the side walls of the body. Like the vitelline veins, the direct connexion of the umbilical veins with

the sinus venosus becomes interrupted by the developing liver, and the whole of the blood from the yolk-sac and placenta passes through the substance of the liver before it reaches the heart. The right umbilical and right vitelline veins shrivel and disappear ; the left umbilical, on the other hand, enlarges and opens into the upper venous ring of the vitelline veins ; with the atrophy of the yolk-sac the left vitelline vein shrivels and disappears. Finally, a direct branch named the *ductus venosus* is established between the upper venous ring and the right hepatic vein ; the ductus venosus enlarges rapidly and forms a wide channel through which most of the blood, returned from the placenta, is carried direct to the heart without passing through the liver. A small part of the blood from the placenta is, however, conveyed

FIG. 189.—Human embryo with the heart and anterior body wall removed to show the sinus venosus and its tributaries. (After His.) (From Kollmann's *Entwicklungsgeschichte*.)



from the left umbilical vein to the liver through the left vena advehens. The left umbilical vein and the ductus venosus are obliterated after birth, and form respectively the ligamentum teres and ligamentum venosum of the liver.

The parietal veins.—A pair of short transverse veins, named the *ducts of Cuvier*, open, one on either side, into the sinus venosus. Each of these ducts receives an ascending and a descending vein. The ascending veins return the blood from the parietes of the trunk and from the Wolfian bodies, and are called *posterior cardinal veins*. The descending veins return the blood from the head, and are called the *anterior cardinal* (primitive jugular) veins (fig. 184). The blood from the lower limbs is collected by the right and left iliac and hypogastric veins, which, in the earlier stages of development, open into the corresponding right and left posterior cardinal veins; later, a transverse branch (the left common iliac vein) is developed between the lower parts of the posterior cardinal veins (fig. 186), and through this the blood is carried into the right posterior cardinal vein. The portion of the left posterior cardinal vein below the left renal vein atrophies and disappears up to the point of entrance of the left testicular vein; the portion above the left renal vein persists

as the hemiazygos and accessory hemiazygos veins and the lower portion of the left superior intercostal vein. The right posterior cardinal vein, which now receives the blood from both lower extremities, forms a large venous trunk along the posterior abdominal wall; up to the level of the renal veins it forms the lower part of the inferior vena cava. Above the level of the renal veins the right posterior cardinal vein persists as the azygos vein and receives the right intercostal veins, while the hemiazygos and accessory hemiazygos veins are brought into communication with it by the development of transverse branches in front of the vertebral column (figs. 186, 187).

Recent observations support the view that the azygos and hemiazygos veins are formed independently of the posterior cardinal veins, and Sabin* has shown, by dissections of injected pig embryos, that the two sets of veins are present at one and the same time. "The posterior cardinal vein is always farther ventral and farther lateral than the azygos."

FIG. 184.—Scheme of the arrangement of the parietal veins.

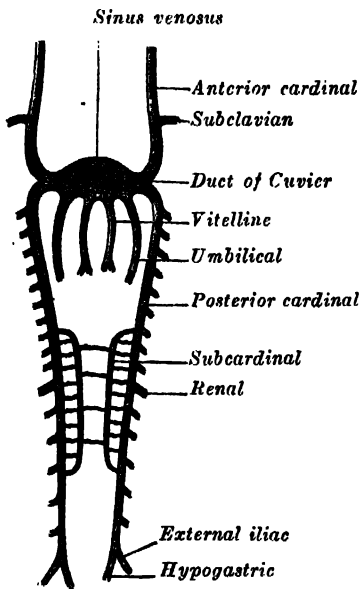
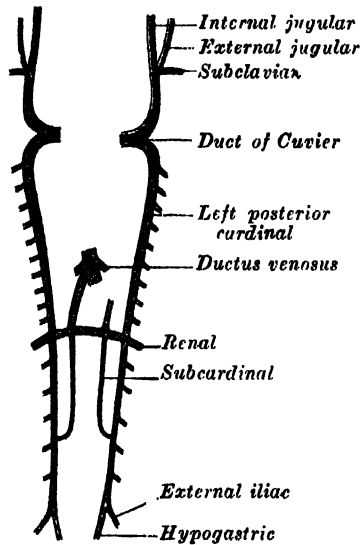


FIG. 185.—Scheme showing the early stages of the development of the inferior vena cava.



Inferior vena cava.—The development of the inferior vena cava is associated with the formation of two veins, the *subcardinal veins* (figs. 184, 185). These run obliquely along the mesial surfaces of the Wolffian bodies parallel to the posterior cardinal veins; they communicate with the posterior cardinal veins above and below, and also by a series of transverse branches. The two subcardinals are for a time connected with each other in front of the aorta by cross branches, but these disappear and are replaced by a single transverse channel at the level where the renal veins join the posterior cardinals, and at the same level a cross communication is established on either side between the posterior cardinal and subcardinal (fig. 185). The portion of the right subcardinal behind this cross communication disappears, while that in front (i.e. the prerenal part) forms a connexion with the right hepatic vein, and, rapidly enlarging, receives the blood from the postrenal part of the right posterior cardinal through the cross communication referred to. In this manner a single trunk, the *inferior vena cava* (fig. 187), is formed, and consists of the proximal part of the right hepatic vein, the prerenal part of the right subcardinal vein, the postrenal part of the right posterior cardinal vein, and the cross branch which joins these two veins. The left subcardinal disappears, except the part immediately in front of the renal vein, which is retained as the left suprarenal vein. The testicular (or ovarian) vein opens into the postrenal part of the corresponding posterior cardinal vein. This portion of the right posterior cardinal, as already explained, forms the lower part of the inferior vena cava, so that the right spermatic opens directly into that vessel. The postrenal segment of the left posterior cardinal

* Sabin, F. *The Anatomical Record*, vol. viii. 1914.

disappears, with the exception of the portion between the testicular and renal veins, which is retained as the terminal part of the left testicular vein.

In consequence of the atrophy of the Wolffian bodies the posterior cardinal veins diminish in size; the anterior cardinal veins, on the other hand, become enlarged, owing to the rapid development of the head and brain. They are further augmented

FIG. 186.—Diagram showing the development of the main cross branches between the cardinal veins.

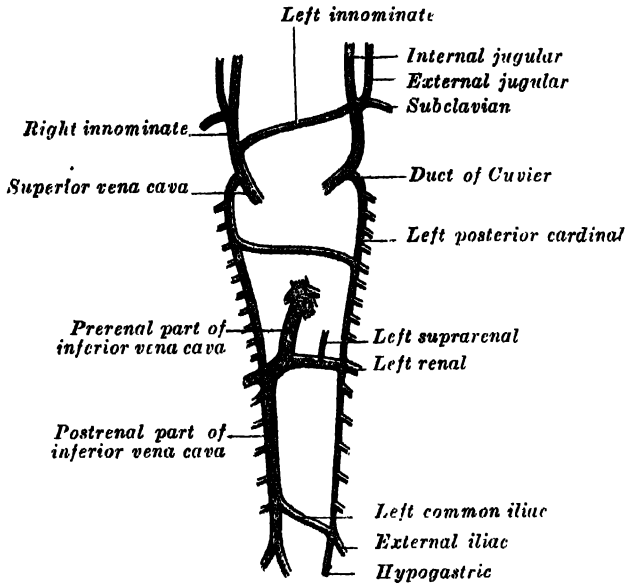
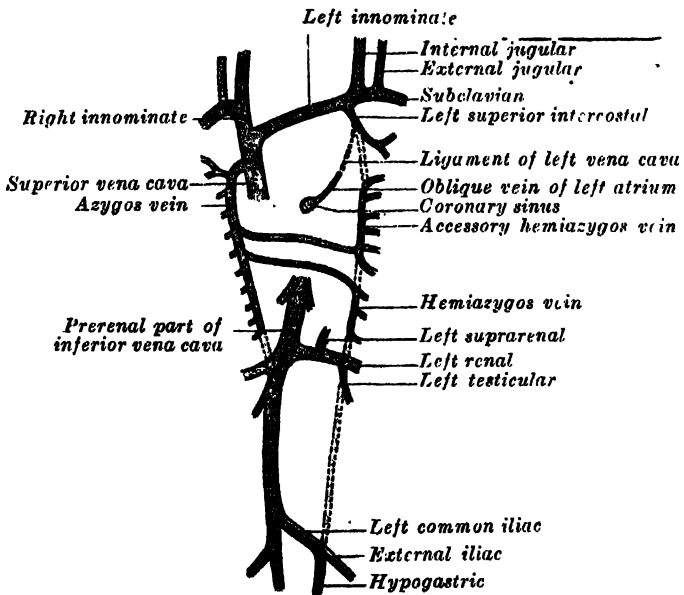


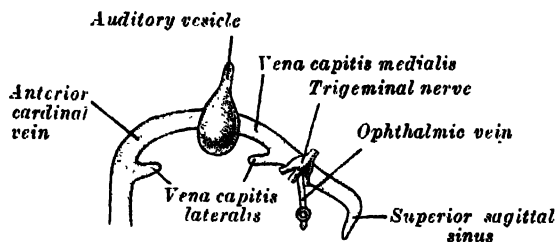
FIG. 187.—Diagram showing the completion of the development of the parietal veins.



by receiving the veins (*subclavian*) from the upper extremities, and so come to form the chief veins of the ducts of Cuvier; these ducts gradually assume an almost vertical position in consequence of the descent of the heart into the thorax. The right and left ducts of Cuvier are originally of the same diameter, and are frequently termed the *right* and *left superior vena cava*. By the development of a transverse branch (the *left innominate vein*) between the two anterior cardinal veins, the blood is carried across from the left to the right anterior cardinal (figs. 186, 187). The

portion of the right anterior cardinal vein between the left innominate and the azygos vein forms the upper part of the superior vena cava of the adult; the lower part of this vessel (i.e. below the entrance of the azygos vein) is formed by the right duct of Cuvier. Below the origin of the transverse branch the left anterior cardinal vein and left duct of Cuvier atrophy, the former constituting the upper part of the left superior intercostal vein, while the latter is represented by the ligament of the left vena cava (vestigial fold of Marshall) and the oblique vein of the left atrium (oblique vein of Marshall) (fig. 187). Both right and left superior venæ cavæ are present in some animals, and are occasionally found in the adult

FIG. 188.—Diagram of the veins of the head of an embryo four weeks old. (After Mall.)

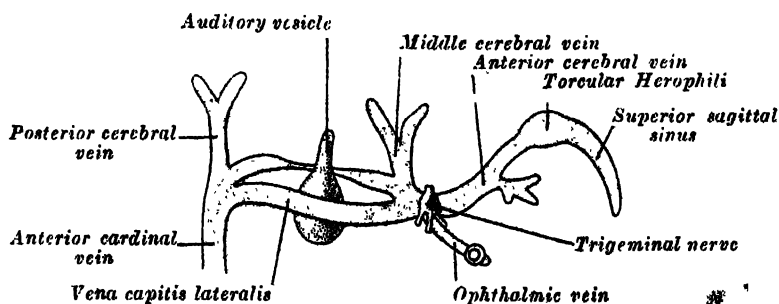


human being. The oblique vein of the left atrium passes downwards across the back of the left atrium to open into the coronary sinus, which, as already indicated, represents the persistent left horn of the sinus venosus.

The anterior cardinal veins drain the blood from the brain, and their proximal parts form the internal jugular veins. The distal

portion of each has been named the vena capitis medialis (fig. 188); it runs on the medial side of the auditory vesicle and cerebral nerve-roots, and the portion of it situated in the neighbourhood of the trigeminal nerve becomes the cavernous sinus. The greater part of the vena capitis medialis is replaced, however, by the vena capitis lateralis (fig. 189), which is developed on the lateral aspect of the cerebral nerves from the trigeminal to the hypoglossal. This vein receives three principal tributaries, viz. the anterior cerebral vein from the eye, fore-brain and mid-brain, the middle cerebral vein from the cerebellum, and the posterior cerebral vein from the lower part of the hind-brain. At this stage, therefore, practically the whole of the blood from the brain is drained into the vena capitis lateralis which leaves the skull in company with the facial nerve and opens into the anterior cardinal vein. The terminal branches of the two anterior cerebral veins anastomose

FIG. 189.—Diagram of the veins of the head of an embryo five weeks old. (After Mall.)



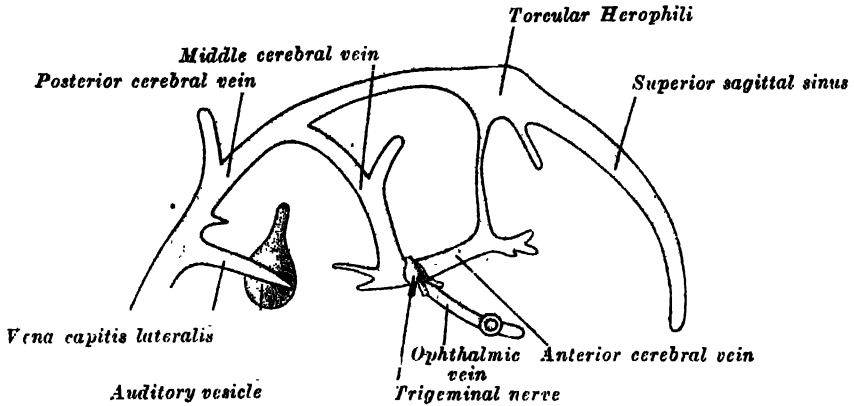
in the middle line and form the superior sagittal sinus (fig. 190). By the backward growth of the cerebral hemispheres this sinus comes to anastomose with the middle and posterior cerebral veins, the latter of which leaves the skull through the jugular foramen; this last anastomosis forms the greater part of the transverse sinus. The vena capitis lateralis atrophies; the middle cerebral vein forms the superior petrosal sinus (fig. 191). The inferior petrosal sinus is a later formation.* The external jugular vein at first drains the region behind the ear (posterior auricular) and enters the anterior cardinal as a lateral tributary. A group of veins from the face and lingual region converge to form a common vein, the linguofacial;† which

* Mall, *American Journal of Anatomy*, vol. iv. 1905.

† Lewis, *American Journal of Anatomy*, vol. ix. 1909.

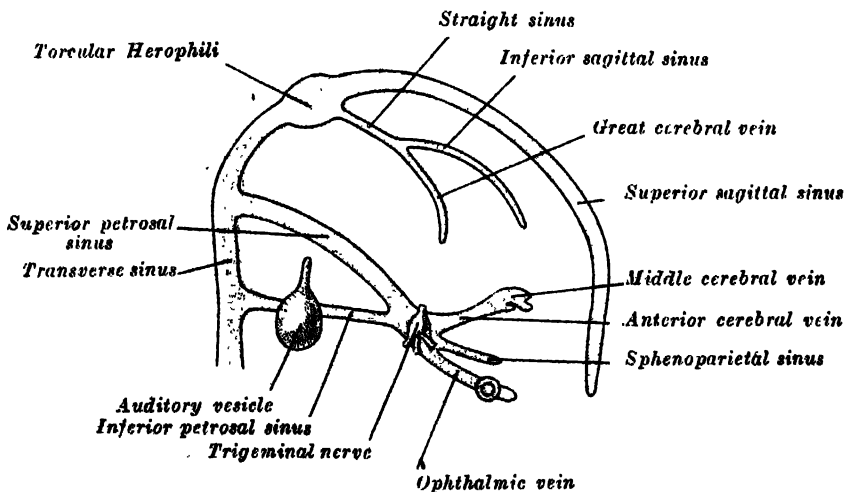
also terminates in the anterior cardinal vein. Later, cross communications develop between the external jugular and the linguofacial, with the result that the posterior group of facial veins is transferred to the external jugular. The cephalic vein is, for a time, a tributary of the external jugular vein, but is later diverted into the axillary vein.

FIG. 190.—Diagram of the veins of the head at the beginning of the third month. (After Mall.)



In early foetal life the heart is placed directly under the head and is relatively of large size. Later it assumes its position in the thorax, but lies at first in the middle line: towards the end of pregnancy it gradually becomes oblique in direction. The atrial portion is at first larger than the ventricular part, and the two atria communicate freely through the foramen ovale. In consequence of the communication, through the ductus arteriosus, between the pulmonary artery and the aorta, the contents of the right ventricle are mainly carried into the latter vessel instead of to the lungs, and hence the wall of the right ventricle is as thick as that of the left. At the end of foetal life, however, the left ventricle is thicker than the right, a difference which becomes more and more emphasised after birth.

FIG. 191.—Diagram of the veins of the head of an older embryo. (After Mall.)



The foetal circulation and the changes which take place in the circulation after birth are described in the section on Angiology.

The Lymphatic Vessels.—The lymphatic system begins as a series of sacs* at the points of junction of certain of the embryonic veins. These lymph-sacs are developed by the confluence of numerous venous capillaries, which at first lose

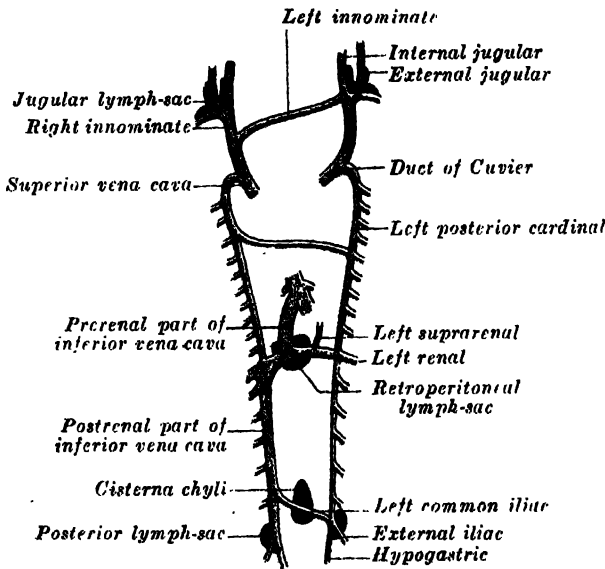
* Sabin, *American Journal of Anatomy*, vol. ix. 1909.

their connexions with the venous system, but subsequently, on the formation of the sacs, regain them. The lymphatic system is therefore developmentally an offshoot of the venous system, and the lining walls of its vessels are always endothelial.

In the human embryo the lymph-sacs from which the lymphatic vessels are derived are six in number; two paired, the jugular and the posterior lymph-sacs; and two unpaired, the retroperitoneal and the cisterna chyli. In lower mammals an additional pair, the subclavian, is present, but in the human embryo these are merely extensions of the jugular sacs.

The position of the sacs is as follows: (1) the jugular, the first to appear, at the junction of the subclavian vein with the anterior cardinal; (2) the posterior, at the junction of the iliac vein with the posterior cardinal; (3) the retroperitoneal,

FIG. 192.—Scheme showing the relative positions of the primary lymph-sacs based on the description given by Florence Sabin.*



in the root of the mesentery near the suprarenal glands; (4) the cisterna chyli, opposite the third and fourth lumbar vertebræ (fig. 192). From the lymph-sacs the lymphatic vessels bud out along fixed lines corresponding more or less closely with the course of the embryonic blood-vessels. In the body-wall and in the wall of the intestine,* the deeper plexuses are the first to be developed; by continued growth of these the vessels in the superficial layers are gradually formed. The thoracic duct is probably formed from anastomosing outgrowths from the jugular sac and cisterna chyli. At its connexion with the cisterna chyli it is at first double, but the two vessels soon join.

All the lymph-sacs except the cisterna chyli are, at a later stage, divided up by slender connective tissue bridges and transformed into groups of lymph-glands. The lower portion of the cisterna chyli is similarly converted, but its upper portion remains as the adult cisterna.

DEVELOPMENT OF THE DIGESTIVE AND RESPIRATORY APPARATUS

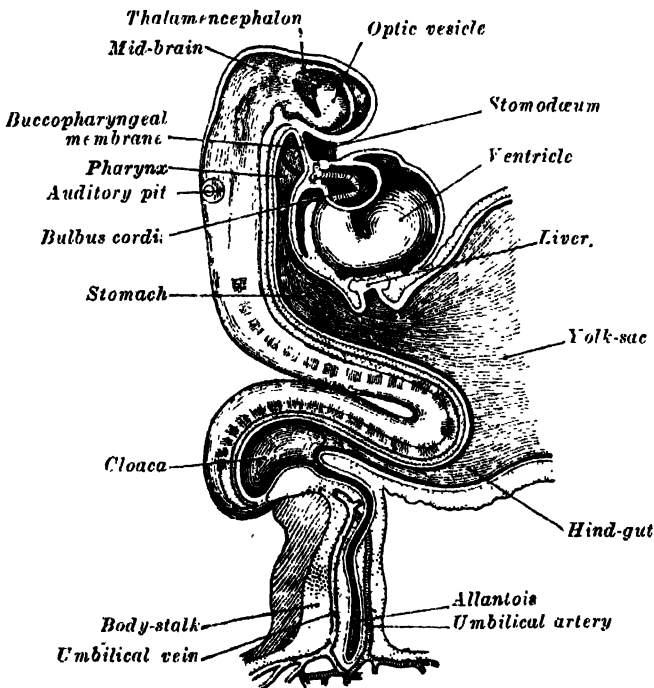
The Digestive Tube.—As already indicated (p. 56), the primitive digestive tube consists of two parts, viz.: (1) the *fore-gut*, within the cephalic flexure, and dorsal to the heart; and (2) the *hind-gut*, within the caudal flexure (fig. 193).

* Heuer, *American Journal of Anatomy*, vol. ix. 1909.

Between these is the wide opening of the yolk-sac, which is gradually narrowed and reduced to a small foramen leading into the vitelline duct. At first the fore-gut and hind-gut end blindly; the anterior end of the fore-gut is separated from the stomodæum by the buccopharyngeal membrane (fig. 193); the hind-gut ends in the cloaca, which is closed by the cloacal membrane.

The mouth.—The mouth is developed partly from the stomodæum, and partly from the floor of the anterior portion of the fore-gut. By the growth of the head-end of the embryo, and the formation of the cephalic flexure, the pericardial area and the buccopharyngeal membrane come to lie on the ventral surface of the embryo. With the further expansion of the brain, and the forward bulging of the pericardium, the buccopharyngeal membrane is depressed between these two prominences. This depression constitutes the *stomodæum* (fig. 193). It is lined by ectoderm, and is separated from the anterior end of the fore-gut by the buccopharyngeal

FIG. 193.—Human embryo about fifteen days old. The brain and heart are represented from right side; the digestive tube and yolk-sac in median section. (After His.)



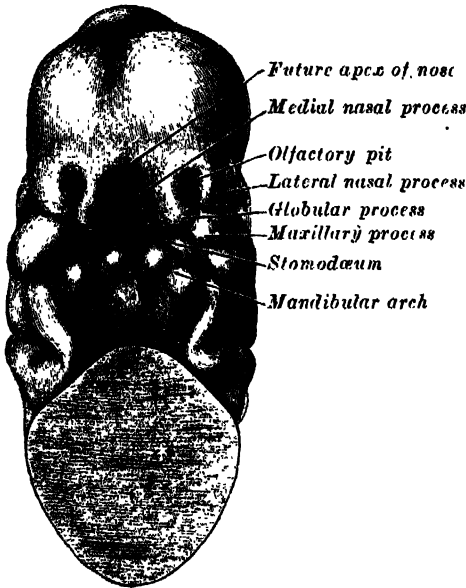
membrane, which is formed by the apposition of the stomodæal ectoderm with the fore-gut entoderm; at the end of the third week the membrane disappears, and a communication is established between the mouth and the future pharynx. No trace of the membrane is found in the adult; and the communication just mentioned must not be confused with the permanent isthmus faucium. The lips, teeth, and gums are formed from the walls of the stomodæum, but the tongue is developed in the floor of the mouth and pharynx.

The visceral arches grow in a ventral direction and lie between the stomodæum and the pericardium; with the completion of the mandibular arch and the formation of the maxillary processes, the mouth assumes the appearance of a pentagonal orifice, bounded in front by the frontonasal process, behind by the mandibular arch, and laterally by the maxillary processes (fig. 194). With the inward growth and fusion of the palatine processes (figs. 123, 124), the stomodæum is divided into an upper nasal and a lower buccal part. Along the free margins of the processes bounding the mouth cavity a shallow groove appears; this is termed the *primary labial groove*, and from the bottom of it a downgrowth of ectoderm into the underlying mesoderm takes place. Owing to the degeneration of the central cells of this ectodermal downgrowth the groove is deepened and a *secondary labial groove* is

formed, and separates the lips and cheeks from the alveolar processes of the maxillæ and mandible.

The **salivary glands** arise as buds from the epithelial lining of the mouth; the parotid appears during the fourth week in the angle between the maxillary process and the mandibular arch; the submaxillary appears in the sixth week, and the sublingual during the ninth week, in the hollow between the tongue and the mandibular arch.

FIG. 194.—Head end of a human embryo of about thirty to thirty-one days. (From model by Peter.)



The tongue (figs. 195 to 197).

—The tongue consists of an anterior or buccal and a posterior or pharyngeal part. During the third week there appears, immediately behind the ventral ends of the two halves of the mandibular arch, a rounded swelling named the *tuberculum impar*, which was described by His as undergoing enlargement to form the buccal part of the tongue. More recent researches, however, show that this part of the tongue is mainly, if not entirely, developed from a pair of lateral swellings which rise from the inner surface of the mandibular arch and meet in the middle line. The tuberculum impar is said to form the central part of the tongue immediately in front of the foramen cæcum, but Hammar insists that it is purely a transitory structure and forms no

part of the adult tongue. From the ventral ends of the fourth arch there arises a second and larger elevation, in the centre of which is a median groove or furrow. This elevation was named by His the *furcula*, and is at first separated from the tuberculum impar by a depression, but later by a ridge, the *copula*, formed by the forward growth and fusion of the ventral ends of the second and third arches. The posterior or pharyngeal part of the tongue is developed from the copula, which

FIG. 195.—Floor of the pharynx of a human embryo about twenty-six days old. (From model by Peter.)

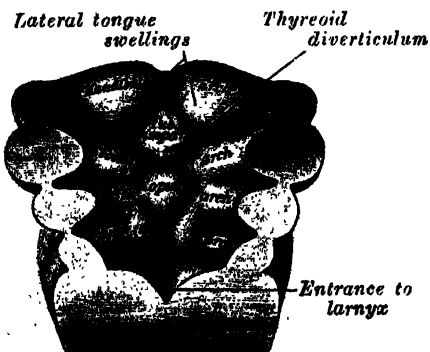
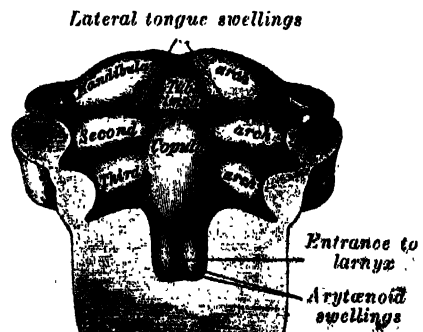


FIG. 196.—Floor of the pharynx of a human embryo of about the end of the fourth week. (From model by Peter.)



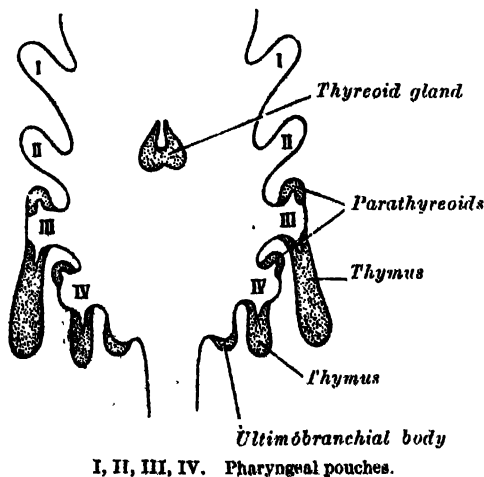
extends forwards in the form of a V, so as to embrace between its two limbs the buccal part of the tongue. At the apex of the V a pit-like invagination occurs, to form the thyroid gland, and this depression is represented in the adult by the *foramen cæcum*. In the adult the union of the anterior and

posterior parts of the tongue is marked by the V-shaped sulcus terminalis, the apex of which is at the foramen cæcum, while the two limbs run lateralwards and forwards parallel to but a little behind the papillæ vallatæ.

The **thyroid gland** is developed from a median diverticulum (fig. 196), which appears about the fourth week on the summit of the tuberculum impar, but later is found in the furrow immediately behind the tuberculum (fig. 195). It grows downwards and backwards as a tubular duct, which bifurcates and subsequently divides into a series of cellular cords, from which the isthmus and lateral lobes of the thyroid gland are developed. As already stated (p. 79), the ultimobranchial bodies from the fifth pharyngeal pouches are enveloped by the lateral lobes of the thyroid gland, but they undergo atrophy and do not form true thyroid tissue. The connexion of the diverticulum with the pharynx is termed the *thyreoglossal duct*; its continuity is subsequently interrupted, and it undergoes obliteration, its upper end being represented by the foramen cæcum of the tongue, and its lower by the pyramidal lobe of the thyroid gland.

The **palatine tonsils** are developed from the dorsal angles of the second pharyngeal pouches. The entoderm which lines these pouches grows in the form of a number of solid buds into the surrounding mesoderm. These buds are excavated by the degeneration and casting off of their central cells, and by this means the tonsillar crypts are formed. Lymphoid cells accumulate around the crypts, and are grouped to form the lymphoid follicles; the latter, however, are not well defined until after birth.

FIG. 198.—Scheme showing the development of branchial epithelial bodies. (Modified from Kohn.)

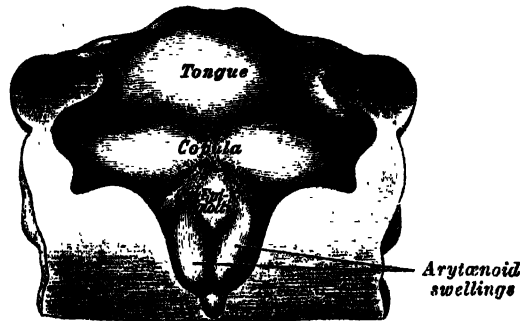


I, II, III, IV. Pharyngeal pouches.

which become surrounded and isolated by the invading mesoderm. In the latter, numerous lymphoid cells make their appearance, and are aggregated to form lymphoid follicles. These lymphoid cells are probably derivatives of the entodermal cells which lined the original diverticula and their subdivisions. Additional portions of thymus tissue are sometimes developed from the fourth branchial pouches. The thymus continues to grow until the time of puberty and then begins to atrophy.

The two pairs of **parathyroid bodies** are developed as outgrowths from the third and fourth branchial pouches (fig. 198); the diverticula from the third pouches migrate to a lower level than those from the fourth pouches, and consequently the inferior pair of parathyroids is derived from the third, and the superior pair from the fourth, pharyngeal pouches.

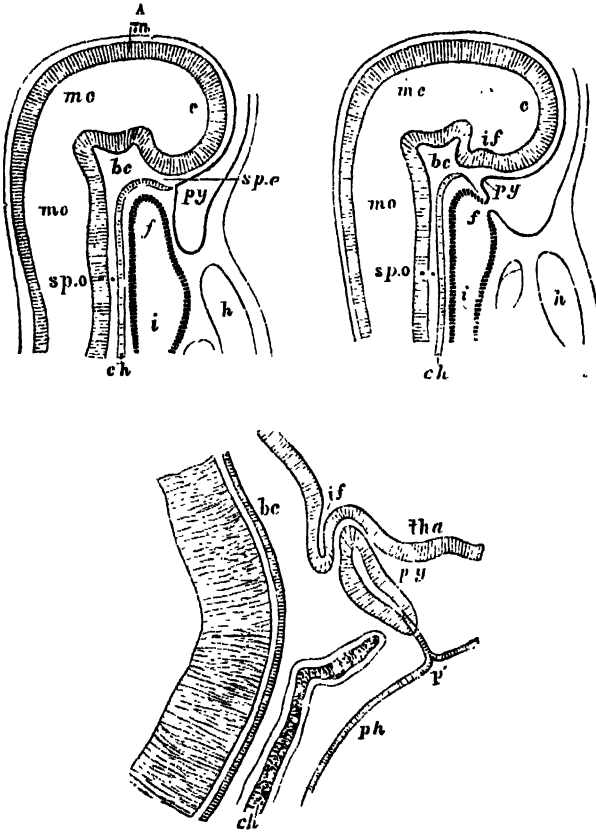
FIG. 197.—Floor of the pharynx of a human embryo of about thirty days old. (From model by Peter.)



Two diverticula arise from the fifth pharyngeal pouches and form what are termed the *ultimobranchial bodies* (fig. 198): these fuse with the thyroid gland, but do not form true thyroid tissue.

The hypophysis cerebri.—In the adult the hypophysis cerebri consists of an anterior and a posterior lobe: the former is derived from the ectoderm of the stomodæum, the latter from the floor of the fore-brain. Previous to the rupture of the buccopharyngeal membrane a pouch-like diverticulum of the ectodermal

FIG. 199.—Vertical sections of the heads of early embryos of the rabbit. Magnified. (From Mihalkovics.)



A. From an embryo of 5 mm. long. B. From an embryo of 6 mm. long. C. Vertical section of the anterior end of the notochord and hypophysis, etc., from an embryo 16 mm. long. In A the buccopharyngeal membrane is still present. In B it is in the process of disappearing, and the stomodæum now communicates with the primitive pharynx. *am.* Amnion. *c.* Fore-brain. *ch.* Notochord. *f.* Anterior extremity of fore-gut. *h.* Heart. *if.* Infundibulum. *m.* Wall of brain cavity. *mc.* Mid-brain. *mo.* Hind-brain. *p.* Original position of hypophysial diverticulum. *py.* *ph.* Pharynx. *sp.e.* Speno-ethmoidal; *bc.* Central, and *sp.o.* Speno-occipital parts of basis cranii. *tha.* Thalamus.

lining of the roof of the stomodæum appears. This diverticulum (*pouch of Rathke*) (figs. 199, 200) is the rudiment of the anterior lobe of the hypophysis; it extends upwards in front of the cephalic end of the notochord and in front of the buccopharyngeal membrane, and comes into contact with the under surface* of the fore-brain. It is then constricted off to form a closed vesicle, but remains for a time connected to the ectoderm of the stomodæum by a solid cord of cells. Masses of epithelial cells form on either side and in the front wall of the vesicle, and by the growth of a stroma from the mesoderm between the masses the development of the anterior lobe is completed. A canal (*craniopharyngeal canal*) sometimes opens from the anterior part of the fossa hypophyseos of the sphenoidal bone on to the under surface of the skull, and marks the original position of Rathke's pouch; while at the junction of the septum of the nose with the palate traces of the stomodæal end of the

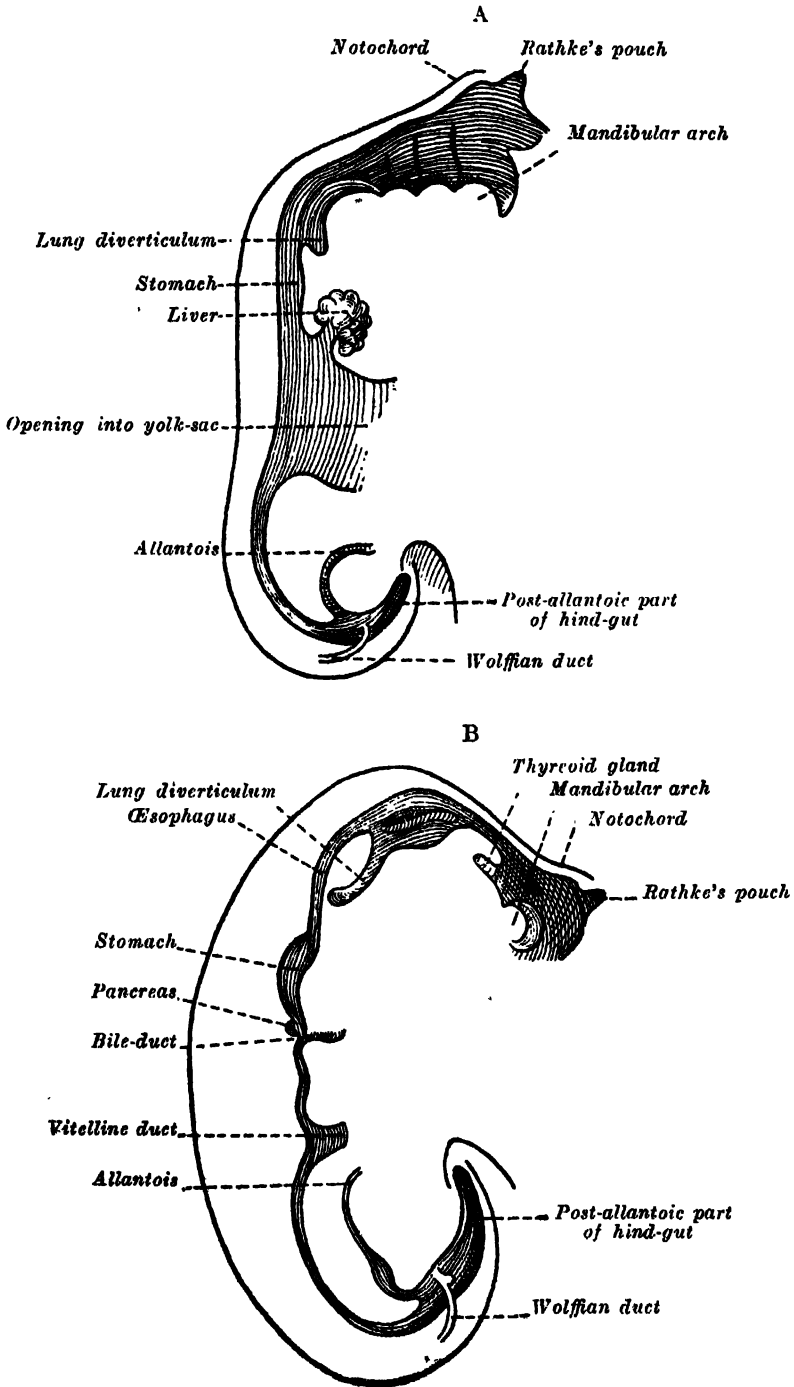
pouch are occasionally present. (Frazer.) The upwardly directed hypophysial involution becomes applied to the anterolateral aspect of a downwardly directed diverticulum from the base of the fore-brain (p. 95). This diverticulum constitutes the future infundibulum of the floor of the third ventricle, and its inferior extremity is modified to form the posterior lobe of the hypophysis. In some of the lower animals the posterior lobe contains nerve-cells and nerve-fibres, but in man and the higher vertebrates these are replaced by connective tissue.

A small entodermal diverticulum, termed *Seessel's pouch*, projects towards the brain from the anterior end of the fore-gut, close to the buccopharyngeal membrane. The fate and significance of this pouch have not yet been determined.

Further Development of the Digestive Tube.—The upper part of the fore-gut dilates to form the pharynx (fig. 193) in the lateral walls of which the branchial arches are developed (see page 77); the succeeding part remains tubular, and is

elongated to form the œsophagus. About the fourth week a fusiform dilatation, the future stomach, makes its appearance, and beyond this the gut opens into the

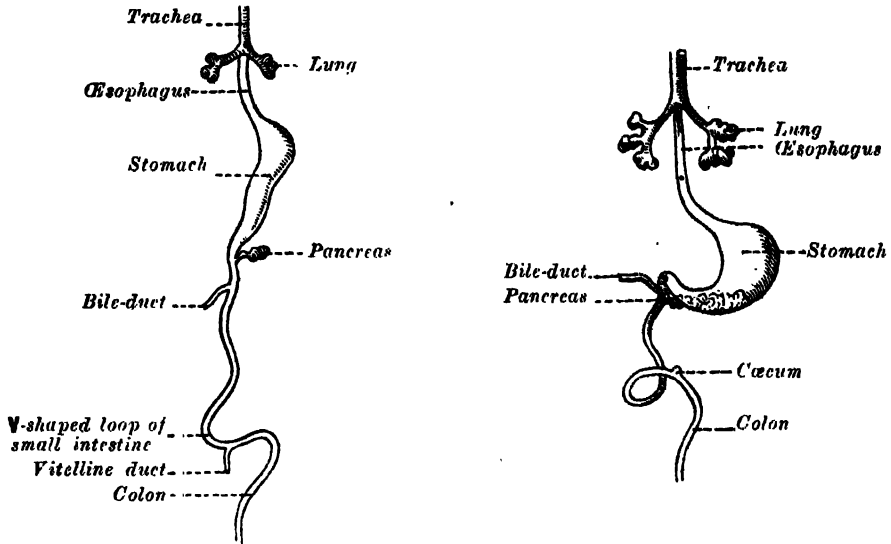
FIG. 200.—Sketches in profile of two stages in the development of the human digestive tube. (His.) Fig. A $\times 30$. Fig. B $\times 20$.



yolk-sac (figs. 200, 201); this opening is at first wide, but is gradually narrowed into a tubular stalk, the *yolk-stalk* or *vitelline duct*. Between the stomach and the mouth of the yolk-sac the liver diverticulum appears. From the stomach to the

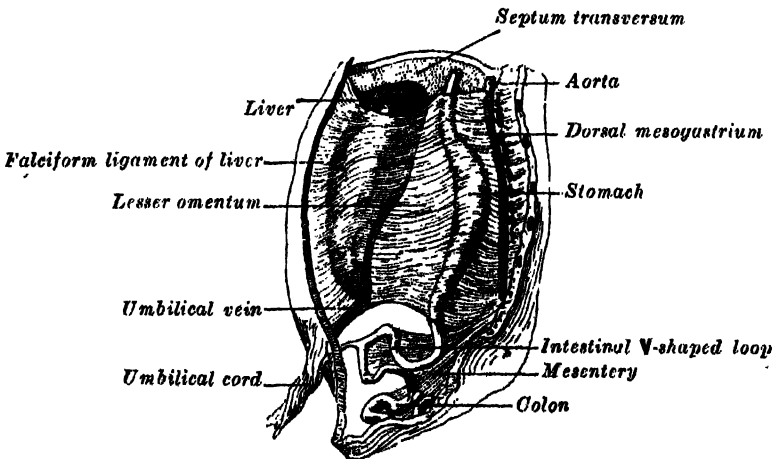
rectum the alimentary canal is attached to the notochord by a band of mesoderm, from which the common mesentery of the gut is subsequently developed. The stomach is also attached to the anterior abdominal wall as far as the umbilicus

FIG. 201.—Front view of two successive stages in the development of the digestive tube. (His.)



by the septum transversum. The cephalic portion of the septum takes part in the formation of the Diaphragm, while the caudal portion into which the liver grows forms the *ventral mesogastrium* (fig. 202). The stomach undergoes a further dilatation, and its two curvatures can be recognised (figs. 200, B, and 201), the greater directed towards the vertebral column and the lesser towards the anterior wall of the abdomen, while its two surfaces look to the right and left respectively. Distal to

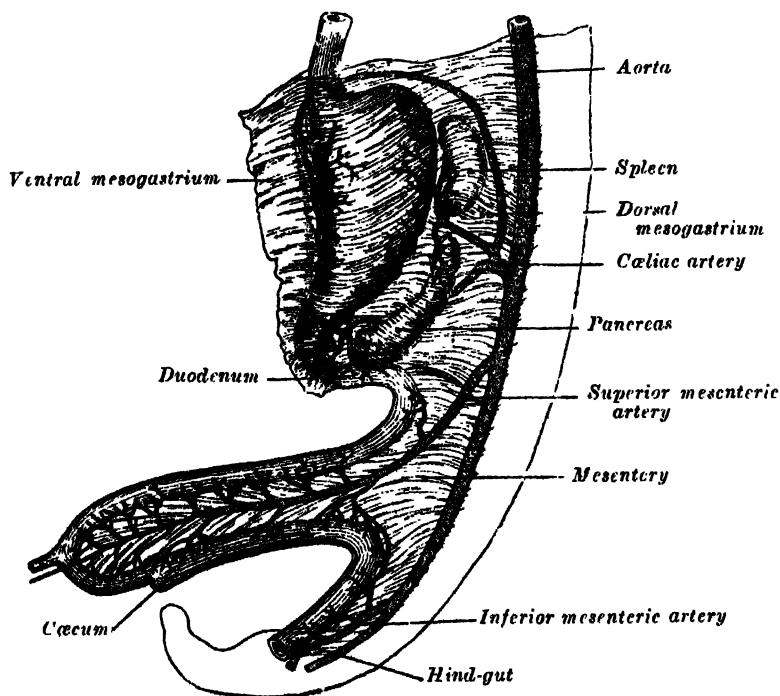
FIG. 202.—The primitive mesentery of a six weeks' human embryo, half schematic. (Kollmann.)



the stomach the gut undergoes great elongation, and forms a V-shaped loop which projects downwards and forwards; from the bend or angle of the loop the vitelline duct opens (fig. 202). For a time a large part of the loop extends beyond the abdominal cavity into the umbilical cord, but by the end of the third month it is

withdrawn within the cavity. With the lengthening of the tube, the mesoderm, which attaches it to the future vertebral column and carries the blood vessels for the supply of the gut, is thinned and drawn out to form the *posterior common mesentery*. The portion of this mesentery attached to the greater curvature of the stomach is named the *dorsal mesogastrium*, and the part which suspends the colon is termed the *mesocolon* (fig. 203). About the sixth week a diverticulum of the gut appears just behind the opening of the vitelline duct, and is differentiated into the future cæcum and vermiform process. The part of the loop on the distal side of the cæcal diverticulum increases in diameter and forms the future ascending and transverse portions of the large intestine. Until the fifth month the cæcal diverticulum has a uniform calibre, but from this time onwards its caudal part remains rudimentary and forms the vermiform process, while its cephalic part expands to form the cæcum. Changes also take place in the shape and position of the stomach. The fundus

FIG. 203.—Abdominal part of digestive tube and its attachment to the primitive or common mesentery. Human embryo of six weeks. (After Toldt.) (From Kollmann's *Entwicklungsgeschichte*.)



is developed as a localised outgrowth or diverticulum from the cardiac end of the greater curvature (Keith and Wood Jones*). F. T. Lewis† points out that in a 16 mm. embryo a canal (gastric canal) passes along the lesser curvature of the stomach from the oesophagus to the pars pylorica, and that in a 44.3 mm. embryo this canal is more distinct than in the earlier stages and reaches from the antrum cardiacum to the incisura angularis.

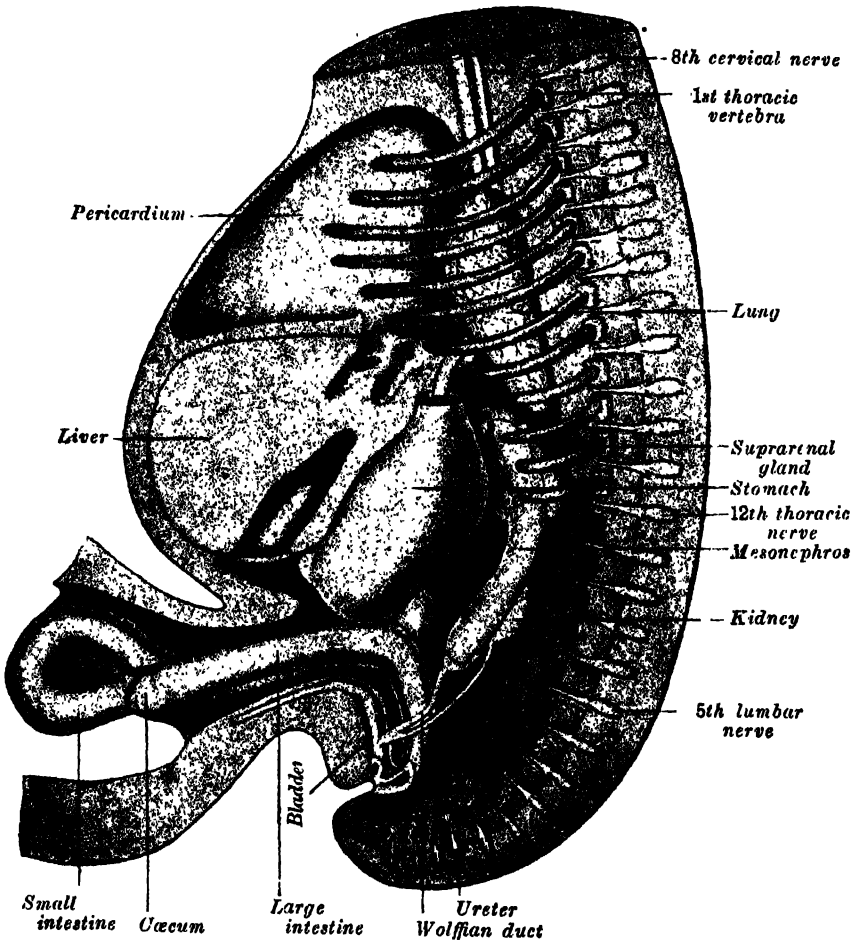
The dorsal part or greater curvature of the stomach, to which the dorsal mesogastrium is attached, grows much more rapidly than its ventral part or lesser curvature, to which the ventral mesogastrium is fixed. The greater curvature is also carried downwards and to the left, and the right surface of the stomach is now directed backwards, and the left surface forwards (fig. 205)—a change in position which explains why the left vagus nerve is found on the front, and the right vagus on the back of the stomach. The dorsal mesogastrium being attached to the greater curvature necessarily follows its movements, and hence it is greatly elongated and drawn lateralwards and ventralwards from the vertebral column,

* *Proceedings of the Anatomical Society of Great Britain and Ireland*, November 1901.

† *American Journal of Anatomy*, vol. xiii. 1912.

and, as in the case of the stomach, the right surfaces of both the dorsal and ventral mesogastria are now directed backwards, and the left forwards. In this way a pouch, the *bursa omentalis*, is formed behind the stomach, and this increases in size as the digestive tube undergoes further development; the entrance to the pouch constitutes the future *epiploic foramen* (foramen of Winslow). The duodenum is developed from that part of the tube which immediately succeeds the stomach; it undergoes little elongation, being more or less fixed in position by the liver and pancreas, which arise as diverticula from it; for a time its lumen is occluded by an epithelial plug. The duodenum is at first suspended by a mesentery, and projects

FIG. 204.—Reconstruction of a human embryo of 17 mm. (After Mall.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



forwards in the form of a loop; but the loop and its mesentery are subsequently displaced by the transverse colon, so that the right surface of the duodenal mesentery is directed backwards, and, adhering to the parietal peritoneum, is lost. The remainder of the digestive tube elongates greatly, and is thrown into coils, and this elongation demands a corresponding increase in the width of the intestinal attachment of the mesentery, which becomes folded.

At this stage the small and large intestines are attached to the vertebral column by a common mesentery, the coils of the small intestine falling to the right of the middle line, while the large intestine lies on the left side.*

* Sometimes this condition persists throughout life, and the duodenum lies entirely on the right side of the median plane, where it is continued into the jejunum; the arteries to the small intestine (jejunal and ileal) arise from the right instead of the left side of the superior mesenteric artery.

The gut is now rotated upon itself, so that the large intestine is carried over in front of the small intestine, and the cæcum is placed immediately below the liver ;

FIG. 205.—Diagrams to illustrate two stages in the development of the digestive tube and its mesentery. The arrow indicates the entrance to the bursa omentalis.

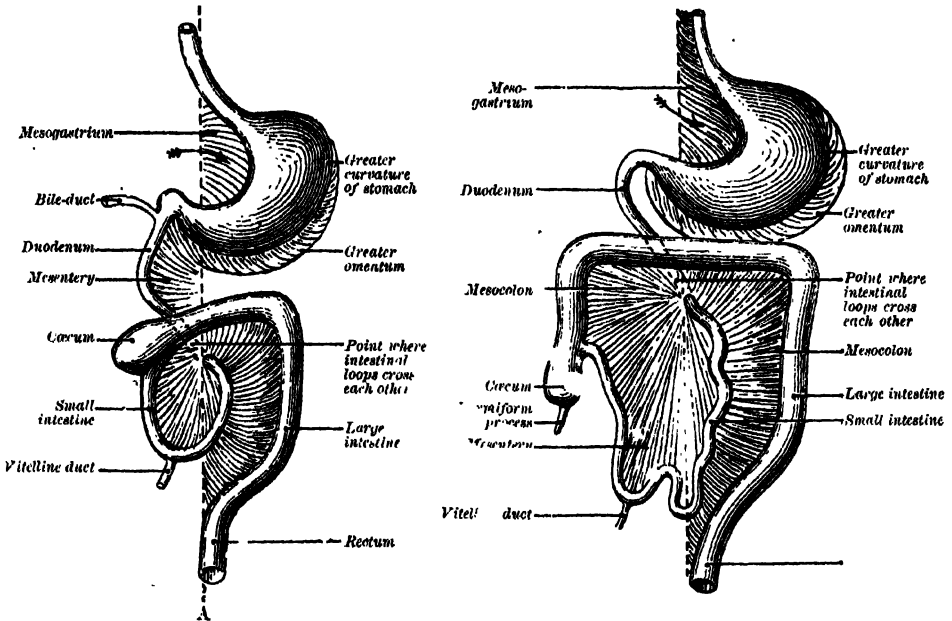
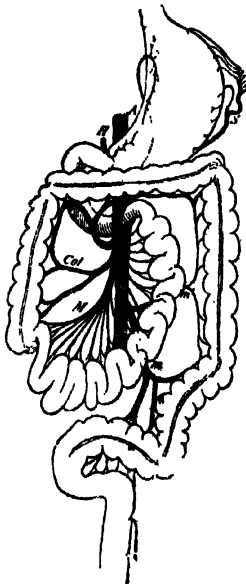
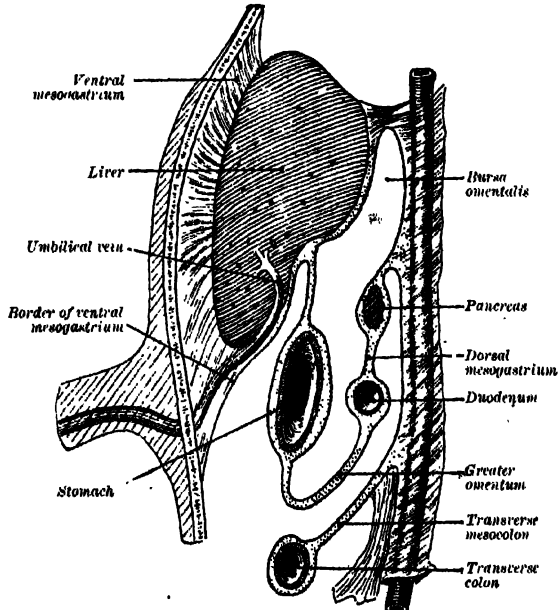


FIG. 206.—Final disposition of the intestines and their vascular relations. (Jonnesco.)



A. Aorta. H. Hepatic artery. M, Col. Branches of superior mesenteric artery. m, m'. Branches of inferior mesenteric artery. S. Splenic artery.

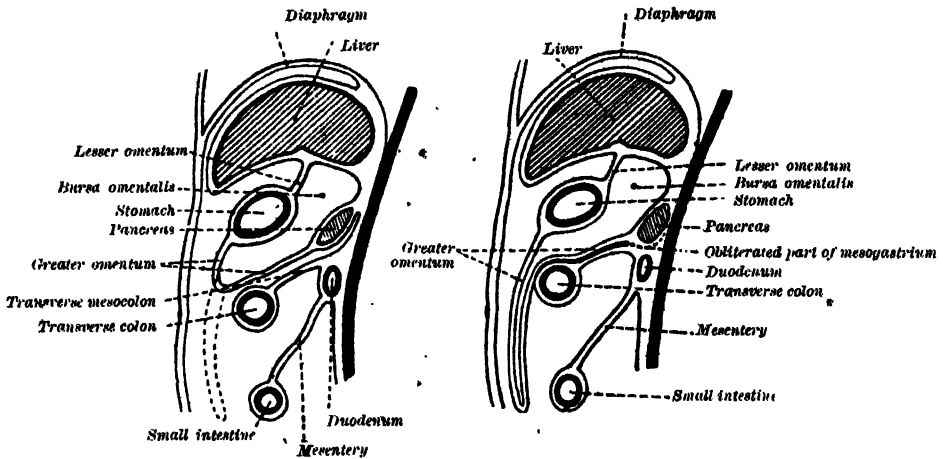
FIG. 207.—Schematic figure of the bursa omentalis, &c. Human embryo of eight weeks. (Kollmann.)



about the sixth month the cæcum descends into the right iliac fossa, and the large intestine forms an arch consisting of the ascending, transverse, and descending

portions of the colon—the transverse portion crossing in front of the duodenum and lying just below the greater curvature of the stomach; within this arch the coils of the small intestine are disposed (fig. 206). Sometimes the downward progress of the cæcum is arrested, so that in the adult it may be found lying immediately below the liver instead of in the right iliac region.*

FIG. 208.—Diagrams to illustrate the development of the greater omentum and transverse mesocolon.



Further changes take place in the bursa omentalis and in the common mesentery, and give rise to the peritoneal relations seen in the adult. The bursa omentalis, which at first reaches only as far as the greater curvature of the stomach, grows downwards and in front of the transverse colon and the coils of the small intestine to form the greater omentum (fig. 207). Before the pleuroperitoneal opening is closed, the bursa omentalis sends a diverticulum upwards on

FIG. 209.—Tail end of a human embryo from fifteen to eighteen days old. (From model by Keibel.)

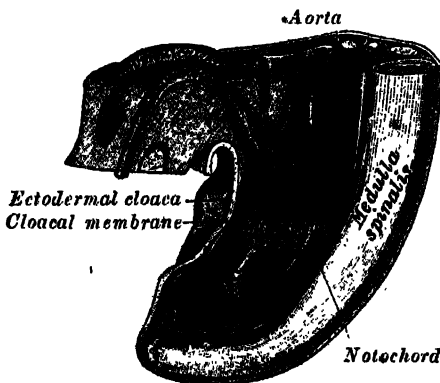
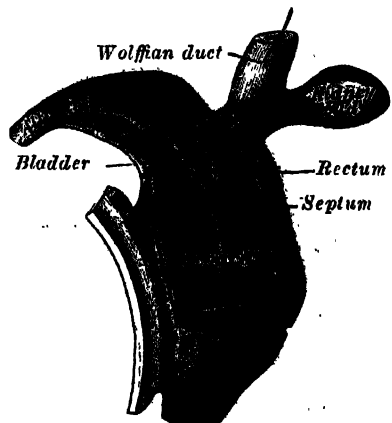


FIG. 210.—Cloaca of a human embryo from twenty-five to twenty-seven days old. (From model by Keibel.)



either side of the œsophagus; the left diverticulum soon disappears, but the right is constricted off and forms the *bursa infracardiaca* which may persist in the adult as a small sac lying within the thorax on the right side of the lower end of the œsophagus. The anterior layer of the transverse mesocolon is at first distinct from the posterior layer of the greater omentum, but the two layers blend, and then the greater omentum appears as if attached to the transverse colon (fig. 208). The

*See article by J. Ernest Frazer and R. H. Robbins 'On the factors concerned in causing rotation of the intestine in man,' *Journal of Anatomy and Physiology*, vol. L.

mesenteries of the ascending and descending parts of the colon disappear in the majority of cases, while that of the small intestine assumes the oblique attachment characteristic of its adult condition.

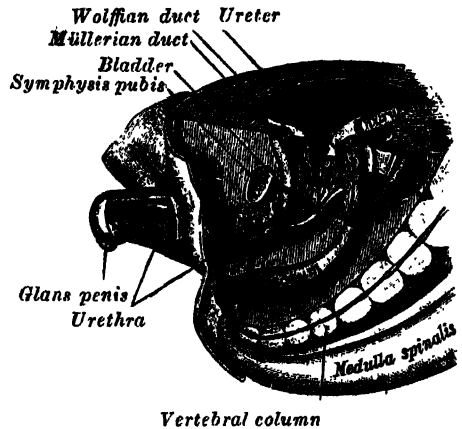
The lesser omentum is formed, as indicated above, by a thinning of the mesoderm (*ventral mesogastrium*) which attaches the stomach and duodenum to the anterior abdominal wall. By the subsequent growth of the liver this leaf of mesoderm is divided into two parts, viz. the lesser omentum between the stomach and liver, and the falciform and coronary ligaments between the liver and the abdominal wall and Diaphragm (fig. 207).

The Rectum and Anal Canal.—The hind-gut is at first prolonged backwards into the body-stalk as the tube of the allantois; but, with the growth and flexure of the tail-end of the embryo, the body-stalk, with its contained allantoic tube, is carried forwards to the ventral aspect of the body, and consequently a bend is formed at the junction of the hind-gut and allantois. This bend dilates to form a pouch, which constitutes the *entodermal cloaca*; into its dorsal part the hind-gut opens, and from its ventral part the allantois passes into the body-stalk. At a later stage the Wolffian and Müllerian ducts open into the ventral portion of the cloaca. The cloaca is, for a time, shut off from the exterior by the *cloacal membrane* which is formed by the apposition of a thick ectodermal and a thin entodermal layer, and reaches at first as far forwards as the future umbilicus. Behind the umbilicus, however, the mesoderm subsequently extends to form the symphysis pubis and the lower part of the abdominal wall. By the growth of the surrounding tissues the cloacal membrane comes to lie at the bottom of a depression, which is lined by ectoderm and named the *ectodermal cloaca* (fig. 209).

The entodermal cloaca is divided into a narrow dorsal and a wide ventral part by means of a partition, the *urorectal septum* (fig. 210), which grows downwards from the ridge separating the allantoic from the cloacal opening of the intestine and ultimately fuses with the cloacal membrane and divides it into an anal and a urogenital membrane. The dorsal part of the cloaca forms the rectum, and the anterior part the urogenital sinus and bladder. For a time a communication named the *cloacal duct* exists between the two parts of the cloaca below the urorectal septum; this duct occasionally persists as a passage between the rectum and the bladder or urethra. By the upgrowth of the surrounding parts the anal part of the cloacal membrane comes to lie at the bottom of a depression, the *proctodæum* or *anal pit*. On the absorption and disappearance of this membrane the rectum communicates with the anal canal (fig. 211). A small part of the hind-gut projects backwards beyond the anal membrane; it is named the *post-anal gut* (fig. 209), and usually becomes obliterated and disappears.*

The Liver arises as a diverticulum from the ventral surface of the fore-gut immediately cranial to the opening of the gut into the yolk-sac (figs. 200, 212). This diverticulum is lined by entoderm, and grows upwards and forwards into the septum transversum which is a mass of mesoderm between the vitelline duct and the pericardial cavity; there the diverticulum gives off two solid buds of cells which represent the right and the left lobes of the liver. The solid buds of cells grow into columns or cylinders, termed the *hepatic cylinders*, which branch and anastomose to form a close meshwork. This network invades the vitelline and umbilical veins, and breaks them up into a series of capillary-like vessels termed *sinusoids* (Minot), which ramify in the meshes of the cellular network. By the continued growth and ramification of the hepatic cylinders the mass of the liver

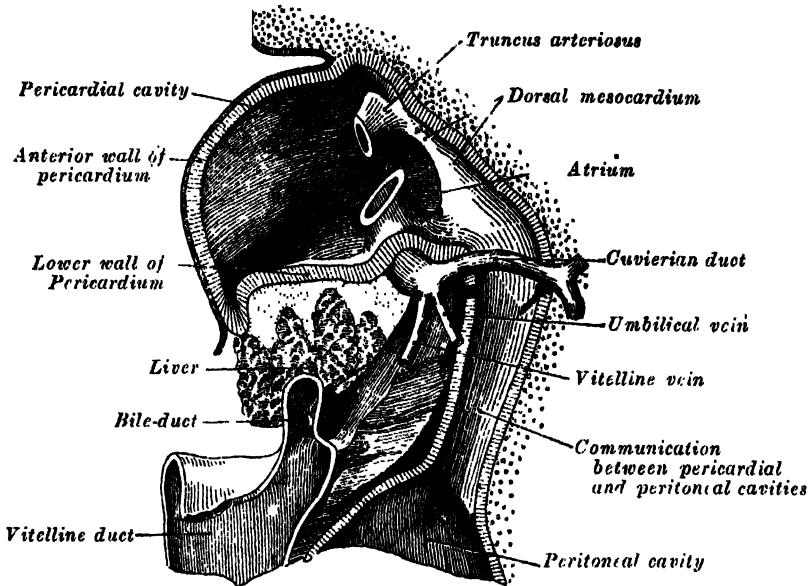
FIG. 211.—Tail end of a human embryo, from eight and a half to nine weeks old. (From model by Keibel.)



* Consult in this connexion the following article: 'A contribution to the morphology of the human urinogenital tract,' by D. Berry Hart, *Journal of Anatomy and Physiology*, vol. xxxv.

is gradually formed. The original diverticulum from the duodenum forms the common bile-duct, and from this the cystic duct and gall-bladder arise as a solid outgrowth which later acquires a lumen. The opening of the common duct is at first in the ventral wall of the duodenum; later, owing to the rotation of the gut

FIG. 212.—Liver with the septum transversum. Human embryo.
(After model and figure by His.)



the opening is carried to the left and then dorsalwards to the position it occupies in the adult.

As the liver undergoes enlargement, both it and the ventral mesogastrium of the fore-gut are gradually differentiated from the septum transversum; and from the under surface of the latter the liver projects downwards into the abdominal cavity. By the growth of the liver the ventral mesogastrium is divided into two parts, of which the anterior forms the falciform and coronary ligaments and the posterior the lesser omentum. About the third month the liver almost fills the abdominal cavity, and its left lobe is nearly as large as its right. From this period

FIG. 213.—Pancreas of a human embryo of five weeks. (Kollmann.)

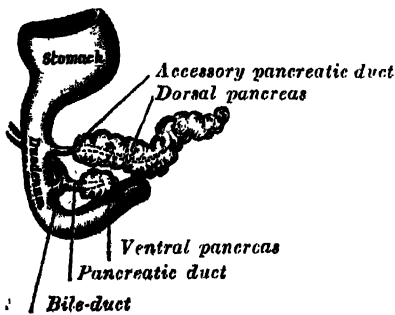
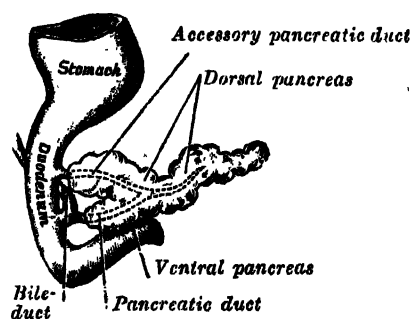


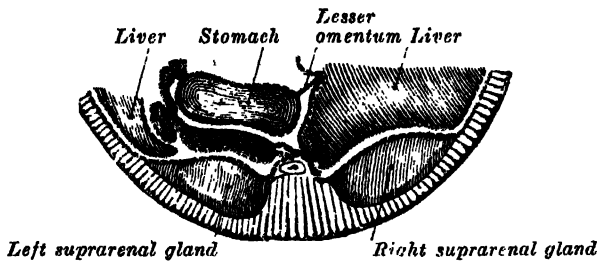
FIG. 214.—Pancreas of a human embryo at end of sixth week. (Kollmann.)



the relative development of the liver is less active, more especially that of the left lobe, which actually undergoes some degeneration and becomes smaller than the right; but up to the end of foetal life the liver remains relatively larger than in the adult.

The Pancreas (figs. 213, 214).—The pancreas is developed in two parts, a dorsal and a ventral. The former arises as a diverticulum from the dorsal wall of the duodenum a short distance above the hepatic diverticulum, and, growing upwards and backwards into the dorsal mesogastrium, forms the whole of the body and tail of the pancreas and a part of the head and uncinæ process. The ventral part appears in the form of a diverticulum from the primitive bile-duct at the spot where the latter opens into the duodenum; from the ventral pancreas the remainder

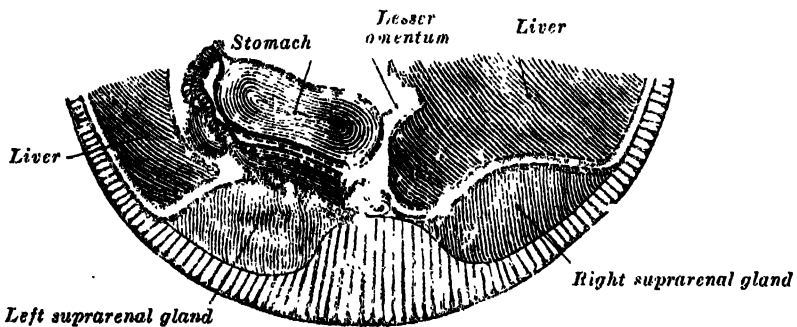
FIG. 215.—Schematic and enlarged transverse section through the body of a human embryo, in the region of the mesogastrium. Beginning of third month. (Toldt.)



of the head and uncinæ process of the pancreas are developed. The duct of the dorsal part (accessory pancreatic duct) therefore opens into the duodenum, while that of the ventral part (pancreatic duct) opens with the common bile-duct. About the sixth week the two parts of the pancreas meet and fuse, and a communication is established between their ducts. After this has occurred the terminal part of the accessory duct, i.e. the part between the duodenum and the point of meeting of the two ducts, undergoes little or no enlargement, while the duct of the ventral part increases in size and forms the main duct of the gland. The opening of the accessory duct into the duodenum is sometimes obliterated, and even when it remains patent it is probable that the whole of the pancreatic secretion is conveyed through the pancreatic duct.

At first the pancreas is directed upwards and backwards between the two layers of the dorsal mesogastrium, which give to it a complete peritoneal investment,

FIG. 216.—Transverse section through same region as in fig. 215, at end of third month. (Toldt.)



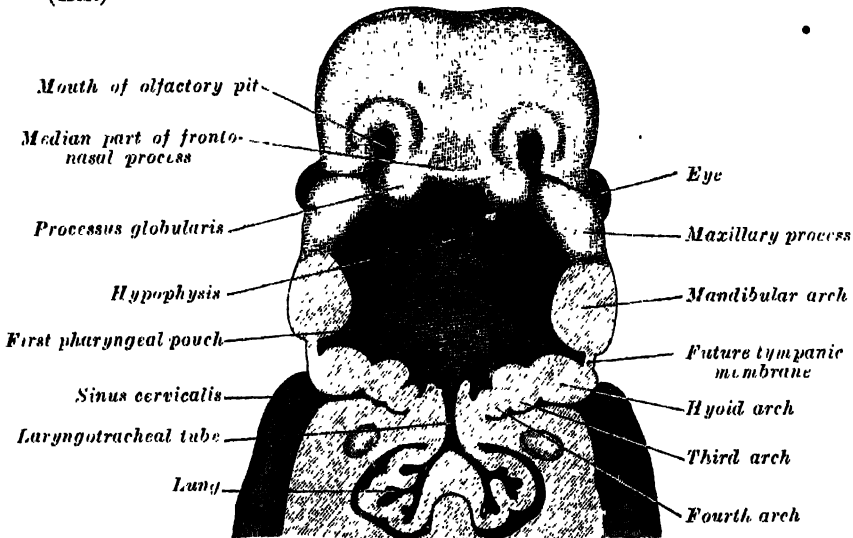
and its surfaces look to the right and left. With the change in the position of the stomach the dorsal mesogastrium is drawn downwards and to the left, and the right side of the pancreas is directed backwards, and the left forwards (fig. 215). The right surface becomes applied to the posterior abdominal wall, and the peritoneum which covers it undergoes absorption (fig. 216); and thus, in the adult, the gland appears to lie behind the peritoneal cavity.

The Spleen (fig. 208).—Although the spleen belongs to the group of ductless glands, its development may be conveniently referred to here. It appears about the fifth week as a localised thickening of the mesoderm in the dorsal mesogastrium above the tail of the pancreas. With the change in position of the stomach the

spleen is carried to the left, and comes to lie behind the stomach and in contact with the left kidney. The part of the dorsal mesogastrium which intervened between the spleen and the greater curvature of the stomach forms the gastrolial ligament.

The Respiratory Organs.—The rudiment of the respiratory organs appears as a median *laryngotracheal groove* in the ventral wall of the pharynx. The groove deepens and its lips fuse to form a septum which grows from below upwards and converts the groove into a tube, the *laryngotracheal tube* (fig. 217), the cephalic end of which opens into the pharynx by a slit-like aperture formed by the persistent anterior part of the groove. The tube is lined by entoderm, and from this the epithelial lining of the respiratory tract is developed. The cephalic part of the tube forms the larynx, and its next succeeding part the trachea, while from its caudal end two lateral outgrowths, the right and left *lung buds*, arise, and from them the bronchi and lungs are developed. The first rudiment of the larynx consists of two *arytænoid swellings*, which appear, one on either side of the cephalic end of the

FIG. 217.—The head and neck of a human embryo thirty-two days old, seen from the ventral surface. The floor of the mouth and pharynx have been removed. (His.)



laryngotracheal groove, and are continuous in front of the groove with a transverse ridge (*furcula* of His) which lies between the ventral ends of the third branchial arches and from which the epiglottis is subsequently developed (figs. 196, 197). After the separation of the trachea from the oesophagus, the arytænoid swellings come into contact with one another and with the back of the epiglottis, and the entrance to the larynx assumes the form of a T-shaped cleft, the margins of the cleft adhere to one another and the laryngeal entrance is for a time occluded. The arytænoid swellings are differentiated into the arytænoid and corniculate cartilages, and the folds joining them to the epiglottis form the aryepiglottic folds in which the cuneiform cartilages are developed as derivatives of the epiglottis. The thyreoid cartilage is developed from the ventral ends of the cartilages of the fourth and fifth branchial arches; it appears as two lateral plates, each chondrified from two centres and united in the mid-ventral line by membrane in which an additional centre of chondrification develops.* The cricoid cartilage arises from two cartilaginous centres, which soon unite ventrally and gradually extend and ultimately fuse on the dorsal aspect of the tube.*

According to J. Ernest Frazer,† who has made an important investigation on the development of the larynx, the glottis or space between the vocal folds is the primary opening of the larynx. During the second and third months a lateral mass (arytænoid swelling), derived from the fourth and fifth arches, grows forward on either side

* See footnotes on p. 78.

† *Journal of Anatomy and Physiology*, vol. xlv:

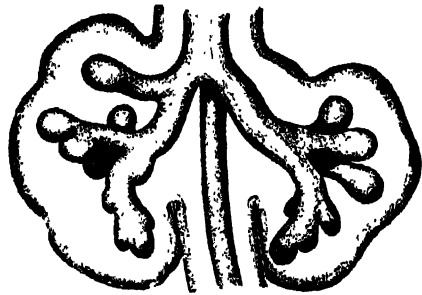
of the primary opening, and from these masses the lateral walls of the vestibule of the larynx are developed. A third elevation or 'central mass' is formed behind the second and third arches. These three masses bound the secondary opening of the larynx. In the lateral masses the arytenoid cartilages and aryepiglottic folds are developed; from the central mass the epiglottis is formed.

The right and left lung buds grow out behind the ducts of Cuvier, and divide into lobules, three appearing on the right, and two on the left, lung-bud; these subdivisions are the early indications of the corresponding lobes of the lungs (figs. 218, 219). The buds undergo further subdivision and ramification, and ultimately

FIG. 218.—Lung buds from a human embryo of about four weeks, showing commencing lobulation. (His.)



FIG. 219.—Lungs of a human embryo more advanced in development. (His.)



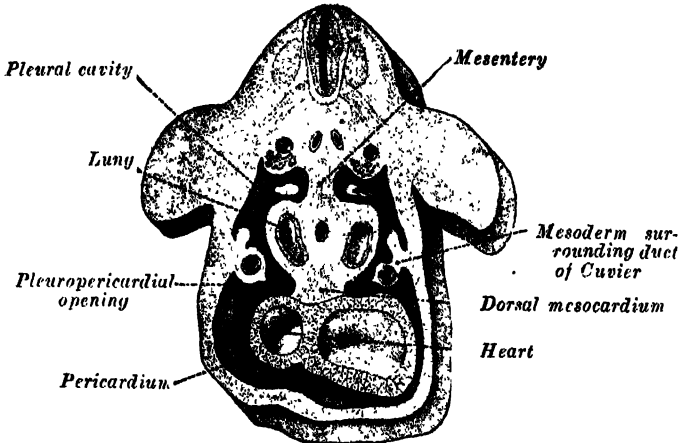
end in minute expanded extremities—the infundibula of the lung. After the sixth month the air-sacs begin to make their appearance on the infundibula in the form of minute pouches. The pulmonary arteries are derived from the sixth aortic arches. During the course of their development the lungs migrate in a caudal direction, so that by the time of birth the bifurcation of the trachea is opposite the fourth thoracic vertebra. As the lungs grow they project into the pleuro-peritoneal canals or parts of the coelum which will ultimately form the pleural sacs, and the splanchnic mesoderm enveloping the lung rudiment expands on the growing lung and is converted into the pulmonary pleura.

DEVELOPMENT OF THE BODY-CAVITIES

In the human embryo described by Peters the mesoderm outside the embryonic disc is split into two layers enclosing an extra-embryonic coelum; there is no trace of an intra-embryonic coelum. At a later stage four cavities are formed within the embryo, viz. one on either side within the mesoderm of the pericardial area, and one in either lateral mass of the general mesoderm. All these are at first independent of each other and of the extra-embryonic coelum, but later they become continuous. The two cavities in the general mesoderm unite on the ventral aspect of the gut and form the pleuroperitoneal cavity, which is continuous for a time with the remains of the extra-embryonic coelum round the umbilicus; the two cavities in the pericardial area rapidly join to form a single pericardial cavity, and from this two lateral diverticula extend caudalwards to open into the pleuroperitoneal cavity (fig. 220). Between the two latter diverticula is a mass of mesoderm containing the ducts of Cuvier, and this is continuous ventrally with the mesoderm in which the umbilical veins are passing to the sinus venosus. A septum of mesoderm thus extends across the body of the embryo. It is attached in front to the body-wall between the pericardium and umbilicus; behind to the body-wall at the level of the second cervical segment; laterally it is deficient where the pericardial and pleuroperitoneal cavities communicate, while it is perforated in the middle line by the fore-gut. This partition is termed the *septum transversum*, and is at first a bulky plate of tissue; from it the principal part of the Diaphragm is formed. As development proceeds the dorsal end of the *septum transversum* is carried gradually caudalwards, and when it reaches the fourth cervical segment muscular tissue with the phrenic nerve grow into it. It continues to recede, however, until

it reaches the position of the adult Diaphragm on the bodies of the upper lumbar vertebræ. As already described (page 139), the liver buds grow into the septum transversum and undergo development there.

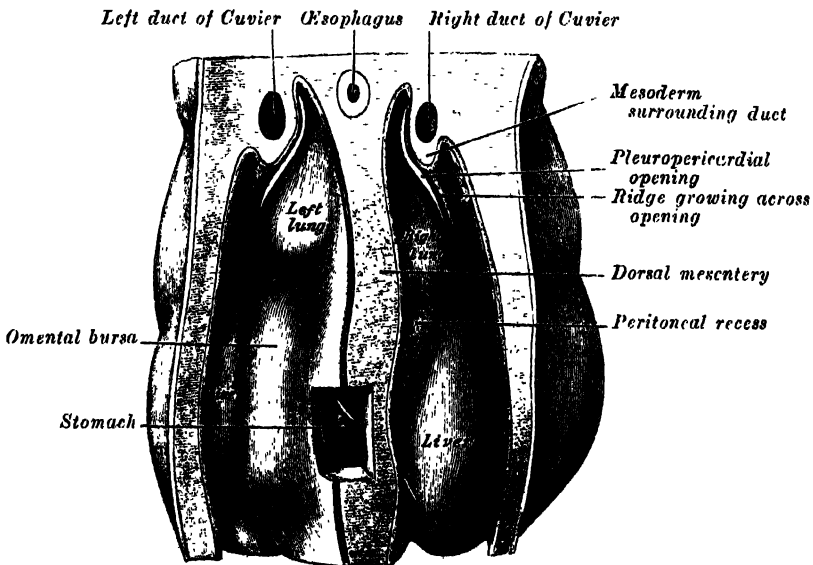
FIG. 220.—Figure obtained by combining several successive sections of a human embryo of about the fourth week. (Kollmann.)



The upper arrow is in the pleuroperitoneal opening, the lower in the pleuropericardial.

The lung buds meantime have grown out from the fore-gut, and project laterally into the forepart of the pleuroperitoneal cavity; the developing stomach and liver are embedded in the septum transversum; caudal to this the intestines project into the back part of the pleuroperitoneal cavity (fig. 204). Owing to the descent of the dorsal end of the septum transversum the lung buds come to lie above the septum, and thus pleural and peritoneal portions of the pleuroperitoneal cavity (still, however, in free communication with one another) may be recognised; the pericardial cavity opens into the pleural part.

FIG. 221.—Upper part of cœlom of human embryo of 6·8 mm. (seen from behind). (From model by Piper.)

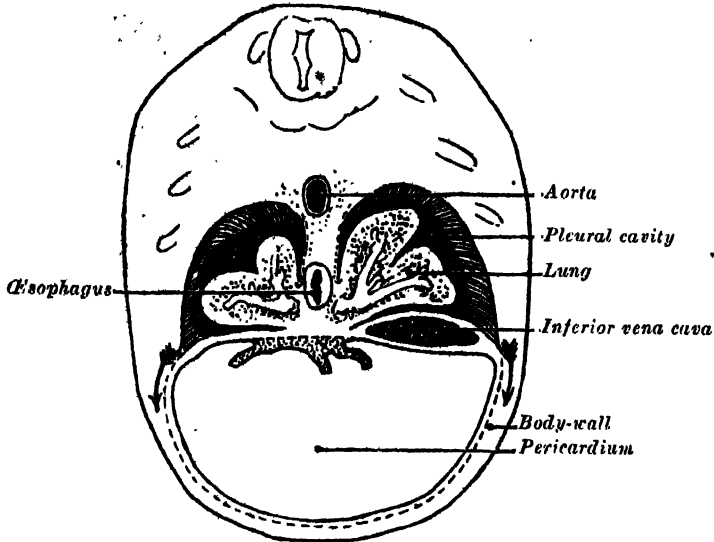


The ultimate separation of the pericardial, pleural, and peritoneal cavities from one another is effected by the growth of a ridge of tissue (*pulmonary ridge* of Mall) on either side from the mesoderm surrounding the duct of Cuvier (figs. 220, 221).

DEVELOPMENT OF URINARY AND GENERATIVE ORGANS 145

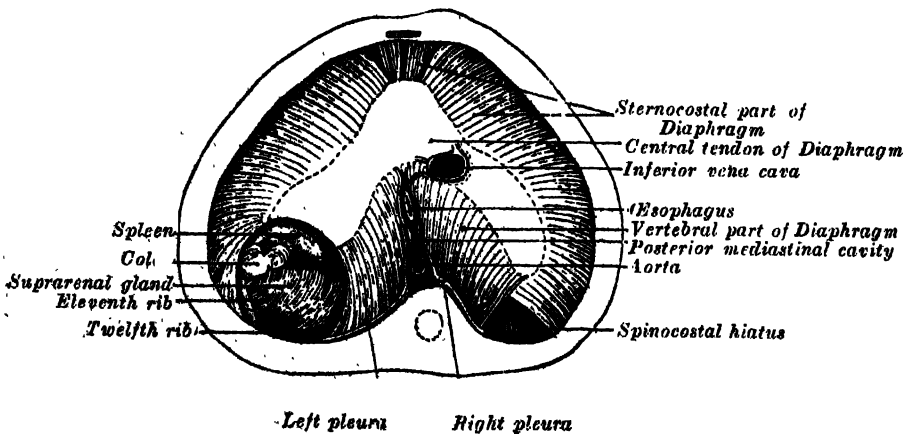
The front or cephalic part of this ridge (pleuropericardial membrane) grows across and obliterates the pleuropericardial opening; the hinder or caudal part (pleuroperitoneal membrane) grows across the pleuroperitoneal opening.

FIG. 222.—Diagram of transverse section through rabbit embryo. (After Keith.)



With the continued growth of the lungs the pleural cavities are pushed forwards in the body-wall towards the ventral median line, thus separating the pericardium from the lateral thoracic walls (fig. 222). The further development of the peritoneal cavity has been described with the development of the digestive tube (page 132 *et seq.*).

FIG. 223.—The thoracic aspect of the Diaphragm of a newly born child in which the communication between the peritoneum and pleura has not been closed on the left side; the position of the opening is marked on the right side by the spinocostal hiatus. (After Keith.)

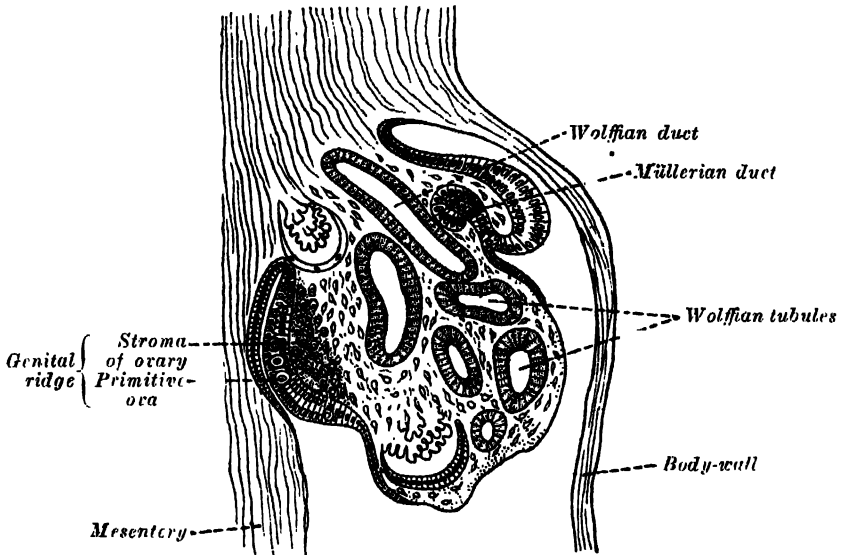


DEVELOPMENT OF THE URINARY AND GENERATIVE ORGANS

The urinary and generative organs are developed from the intermediate cell-mass which is situated between the primitive segments and the lateral plates of mesoderm. The permanent organs of the adult are preceded by a set of embryonic structures on either side; these consist of the pronephros, the mesonephros, the metanephros,

and the Wolffian and Müllerian ducts. The pronephros disappears very early; the structural elements of the mesonephros mostly degenerate, but in their place is developed the genital gland in association with which the Wolffian duct remains as the duct of the male genital gland, the Müllerian as that of the female; some of the tubules of the metanephros form part of the permanent kidney.

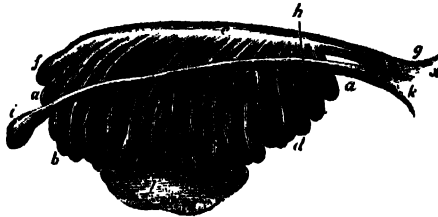
FIG. 224.—Section of the urogenital fold of a chick embryo of the fourth day. (Waldeyer.)



The Pronephros and Wolffian duct.—In the outer part of the intermediate cell-mass, immediately under the ectoderm, in the region from about the fifth cervical to the third thoracic segment, short evaginations from each segment grow dorsalwards and extend caudalwards, fusing successively from before backwards to form the *pronephric duct*. This duct continues to grow caudalwards until it opens into the ventral part of the cloaca; beyond the pronephros it is termed the *Wolffian duct*.

The original evaginations form a series of transverse tubules each of which communicates by means of a funnel-shaped ciliated opening with the coelomic

FIG. 225.—Enlarged view, from the front, of the left Wolffian body before any distinction of sex has appeared. (From Farre, after Kobelt.)



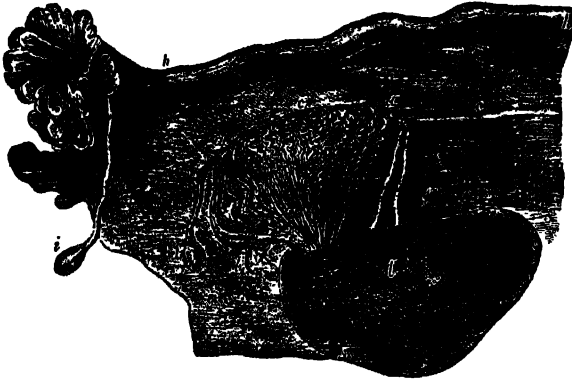
a, a, b, c, d. Tubular structure of the Wolffian body. *e.* Wolffian duct. *f.* Its upper extremity. *g.* Its termination in *x*, the urogenital sinus. *h.* Müllerian duct. *i.* Its upper, funnel-shaped extremity. *k.* Its lower end, terminating in the urogenital sinus. *l.* The genital gland. *x.* Urogenital sinus.

cavity, and in the course of each duct a glomerulus also is developed. Secondary glomeruli are formed, and the complete group constitutes the *pronephros*. The tubules of the pronephros undergo rapid atrophy and disappear, but the Wolffian duct persists as the duct of the mesonephros.

The Mesonephros, Müllerian duct, and Genital gland.—On the medial side of the Wolffian duct, and extending from the sixth cervical to the third lumbar segment, the *Wolffian tubules* (fig. 224) are developed. Each tubule first appears as

a solid mass of cells, which later becomes hollowed in the centre; one end grows towards and finally opens into the Wolffian duct, the other dilates and is invaginated by a tuft of capillary blood-vessels to form a glomerulus. The tubules collectively constitute the *mesonephros* or *Wolffian body* (figs. 204, 225). By the fifth or sixth

Fig. 226.—Broad ligament of adult, showing epoöphoron.
(From Farro, after Kobelt.)



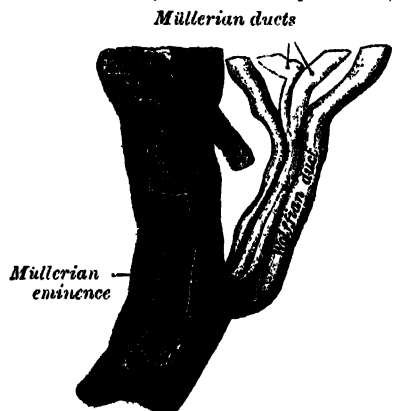
a, a. Epoöphoron formed from the upper part of the Wolffian body. *b.* Remains of the uppermost tubes, sometimes forming appendices. *c.* Middle set of tubes. *d.* Some lower atrophied tubes. *e.* Atrophied remains of the Wolffian duct. *f.* The terminal bulb or hydatid. *h.* The uterine tube, originally the Müllerian duct. *i.* Appendix attached to the extremity. *l.* The ovary.

week this body forms an elongated spindle-shaped structure, termed the *urogenital fold* (fig. 224), which projects into the coelomic cavity on either side of the dorsal mesentery, reaching from the septum transversum in front to the fifth lumbar segment behind; in these folds the genital glands are developed. The Wolffian bodies persist and form the permanent kidneys in fishes and amphibians, but in reptiles, birds, and mammals they atrophy and for the most part disappear coincidently with the development of the permanent kidneys. The atrophy begins during the sixth or seventh week and proceeds rapidly, so that by the beginning of the fifth month only the ducts and a few of the tubules remain.

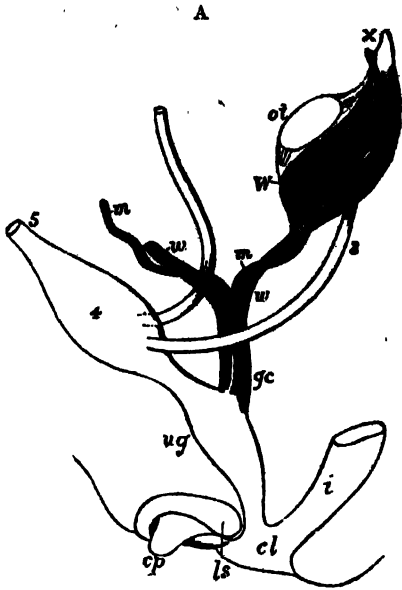
In the male the Wolffian duct persists, and forms the tube of the epididymis, the ductus deferens, and the ejaculatory duct; during the third month the seminal vesicle arises as a lateral diverticulum from the hinder end of the duct. A large part of the head end of the mesonephros atrophies and disappears; of the remainder the anterior tubules form the efferent ducts of the testis; while the posterior tubules are represented by the ductuli aberrantes, and by the paradidymis which is sometimes found in front of the spermatic cord above the head of the epididymis (fig. 228, C).

In the female the Wolffian bodies and ducts atrophy. The remains of the Wolffian tubules are represented by the epoöphoron or organ of Rosenmüller, and the paroöphoron, two small collections of rudimentary, blind tubules which are situated in the mesosalpinx (fig. 226). The lower part of the Wolffian duct disappears, while the upper part persists as the longitudinal duct of the epoöphoron or duct of Gärtner* (fig. 228, B).

Fig. 227.—Urogenital sinus of a female human embryo, from eight and a half to nine weeks old. (From model by Keibel.)

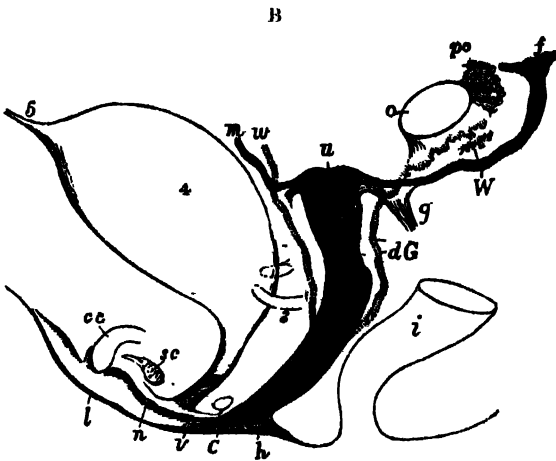


* Berry Hart (*op. cit.*) has described the Wolffian ducts as ending at the site of the future hymen in bulbous enlargements, which he has named the *Wolffian bulbs*; and states that the hymen is formed by these bulbs, 'aided by a special involution from below of the cells lining



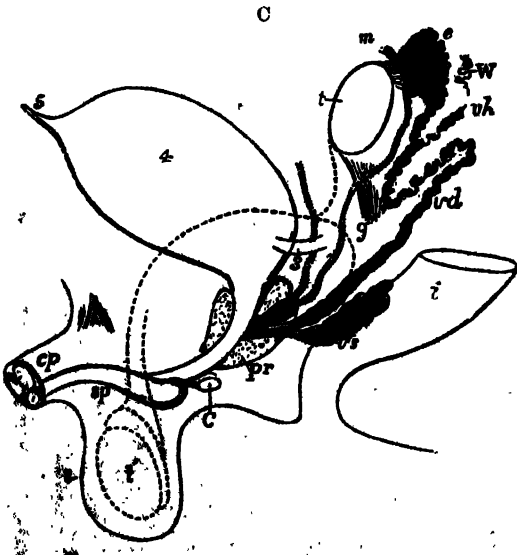
A.—Diagram of the primitive urogenital organs in the embryo previous to sexual distinction.

3. Ureter. 4. Urinary bladder. 5. Urachus. *cl.* Cloaca. *cp.* Elevation which becomes clitoris (or penis). *i.* Lower part of the intestine. *gc.* Genital cord. *ls.* Fold of integument from which the labia majora (or scrotum) are formed. *m, m.* Right and left Müllerian ducts uniting together and running with the Wolffian ducts in *gc.* the genital cord. *ot.* The genital ridge from which either the ovary (or testis) is formed. *ug.* Sinus urogenitalis. *W.* Left Wolffian body. *w, w.* Right and left Wolffian ducts.



B.—Diagram of the female type of sexual organs.

C. Greater vestibular gland, and immediately above it the urethra. *cc.* Corpus cavernosum clitoridis. *dG.* Remains of the left Wolffian duct, persisting as the duct of Gärtner, represented by dotted lines; that of the right side is marked *w.* *f.* The abdominal opening of the left uterine tube. *g.* Round ligament, corresponding to gubernaculum. *h.* Situation of the hymen. *i.* Lower part of the intestine. *l.* Labium majus. *n.* Labium minus. *o.* The left ovary. *po.* Epöphoron. *sc.* Corpus cavernosum urethrae. *u.* Uterus. The uterine tube of the right side is marked *m.* *v.* Vulva. *va.* Vagina. *W.* Scattered remains of Wolffian tubes near it (paröphoron of Waldeyer). *wo.* Right Wolffian duct.



C.—Diagram of the male type of sexual organs.

C. Bulbo-urethral gland of one side. *cp.* Corpora cavernosa penis cut short. *e.* Caput epididymis. *g.* The gubernaculum. *i.* Lower part of the intestine. *m.* Müllerian duct, the upper part of which remains as the hydatid of Morgagni; the lower part, represented by a dotted line descending to the prostatic utricle, constitutes the occasionally existing cornu and tube of the uterus masculinus. *pr.* The prostate. *s.* Scrotum. *sp.* Corpus cavernosum urethrae. *t.* Testis in the place of its original formation. *t'*, together with the dotted lines above, indicates the direction in which the testis and epididymis descend from the abdomen into the scrotum. *vd.* Ductus deferens. *vh.* Ductulus aberrans. *W.* The vesicula seminalis. *W.* Scattered remains of the Wolffian body, constituting the organ of Giraldes, or the paratidymis of Waldeyer.

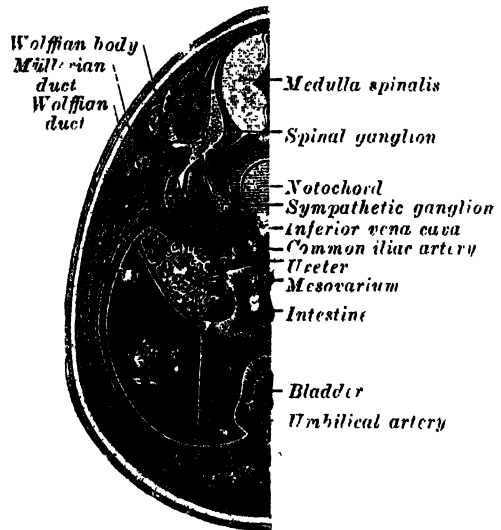
The Müllerian ducts.—Shortly after the formation of the Wolffian ducts a second pair of ducts is developed; these are named the *Müllerian ducts*. Each arises on the lateral aspect of the corresponding Wolffian duct as a tubular invagination of the cells lining the coelom (fig. 224). The orifice of the invagination remains patent, and undergoes enlargement and modification to form the abdominal ostium of the uterine tube. The ducts pass backwards, and run at first lateral to the Wolffian ducts; towards the posterior end of the embryo they cross to the medial side of the Wolffian ducts, and run side by side between and behind them—the four ducts forming what is termed the *genital cord* (fig. 227). The Müllerian ducts end on the *Müllerian eminence*, an epithelial elevation in the ventral part of the cloaca between the orifices of the Wolffian ducts; at a later date they open into the cloaca in this situation.

In the male the Müllerian ducts atrophy, but traces of their anterior ends are represented by the appendices of the testes (hydatids of Morgagni), while their terminal fused portions form the utricle which opens into the floor of the prostatic portion of the urethra (fig. 228, C).

In the female the Müllerian ducts persist and undergo further development. The portions which lie in the genital cord fuse to form the uterus; the parts in front of this cord remain separate, and each forms the corresponding uterine tube—the abdominal ostium of which is developed from the anterior extremity of the original tubular invagination from the coelom (fig. 228, B). The fusion of the Müllerian ducts begins in the third month, and the septum formed by their fused medial walls disappears from below upwards, and thus the cavity of the uterus is produced. In some animals, and occasionally in the human subject, the septum persists, giving rise to a bicornuate uterus. About the fifth month an annular constriction marks the position of the neck of the uterus, and after the sixth month the walls of the uterus begin to thicken. The vagina is formed from two solid extensions from the ends of the Müllerian ducts; these grow at first as solid cords which push their way towards the urogenital septum. The ends fuse with one another, and by the breaking down of the central cells the cavity of the vagina results, and this cavity opens on the exterior through the urogenital septum; a portion of the septum remains to form the hymen.

Genital glands.—The first appearance of the genital gland is essentially the same in the two sexes, and consists of a thickening of the epithelial layer which lines the coelomic cavity on the medial side of the urogenital fold (fig. 224). The thick plate of epithelium extends deeply, and, pushing the mesoderm before it, forms a distinct projection. This is termed the *genital ridge* (fig. 224), and from it the testis in the male and the ovary in the female are developed. At first the mesonephros and genital ridge are suspended by a common mesentery, but as the embryo grows the genital ridge is gradually pinched off from the mesonephros, with which it is at first continuous, though it still remains connected to the remnant of this body by a fold of peritoneum, the *mesorchium* or *mesovarium* (fig. 229). The distinction of sex in the genital ridge is perceptible about the seventh week.

FIG. 229.—Transverse section of human embryo, from eight and a half to nine weeks old. (From model by Keibel.)

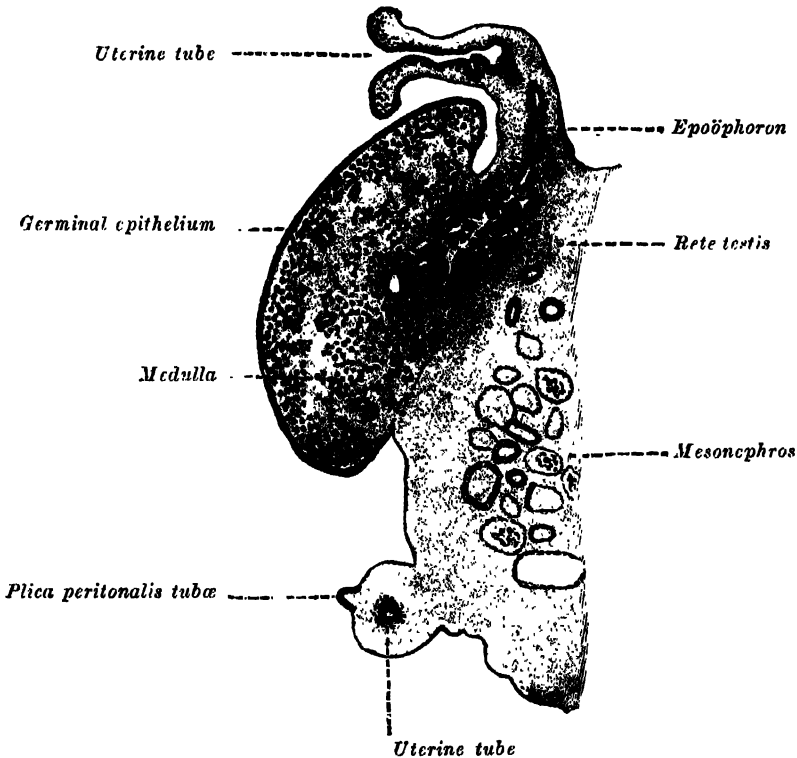


the urogenital sinus. He further believes that 'the lower third of the vagina is due to the coalescence of the upper portion of the urogenital sinus and the lower ends of the Wolffian ducts,' and that 'the epithelial lining of the vagina is derived from the Wolffian bulbs.' He also regards the *colliculus seminalis* of the male urethra as being formed from the lower part of the Wolffian ducts.

In a 10 mm. embryo the genital gland reaches from about the sixth to the twelfth thoracic segment. It subsequently extends as far as the second sacral segment, but simultaneously with this caudal extension the cranial three-fourths of the gland undergo degeneration.

The ovary, formed from the genital ridge, is at first a group of cells derived from the coelomic epithelium; later the group is differentiated into a central mass and a layer of surface epithelium (fig. 230). Between the cells of the surface epithelium a number of larger cells, the *primitive ova*, are found, and these are carried into the subjacent stroma by bud-like ingrowths (*genital cords*) of the surface epithelium (fig. 231). The surface epithelium ultimately forms the permanent epithelial covering of this organ; it loses its connexion with the central mass of cells, and

FIG. 230.—Longitudinal section of ovary of cat embryo, 9.4 cm. long. (Schematic.)
(After Coert, from Hertwig's *Handbuch der Entwicklungslehre*.)



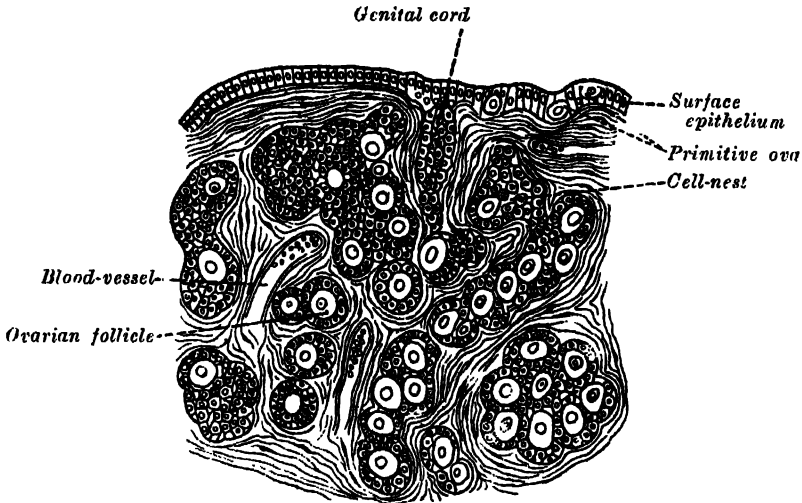
a tunica albuginea develops between them. The ova are chiefly derived from the cells of the central mass; the latter are separated from one another by an irregular growth of connective tissue; each ovum assumes a covering of connective tissue (follicle) cells, and in this way the rudiments of the ovarian follicles are formed (fig. 231).

It was formerly supposed that the primitive germ-cells were derived from the coelomic epithelium covering the genital ridge, but it has been shown that, in the lower vertebrates at least, they are probably formed during the later stages of cell-cleavage. They can be distinguished from the somatic cells by the large size of their bodies and nuclei, and by their cytoplasm which is only faintly granular and has no affinity for ordinary stains, but assumes a brownish colour when treated by osmic acid. These primitive germ-cells migrate first into the root of the mesentery and from there into the coelomic epithelium covering the genital ridge. A considerable number apparently never reach their proper destination, since 'vagrant germ-cells are found in all sorts of places, but more particularly on the mesentery.* Some of these may possibly find their way into the germinal ridge; some probably undergo atrophy, while others may persist and become the seat of dermoid tumours.

* Beard, *Journal of Anatomy and Physiology*, vol. xxxviii,

The testis is developed in much the same way as the ovary. Like the ovary, in its earliest stages it consists of a central mass of epithelium covered by a surface epithelium. In the central mass a series of epithelial cords (testis-cords) appear (fig. 232); simultaneously the peripheral part of the central mass is converted into

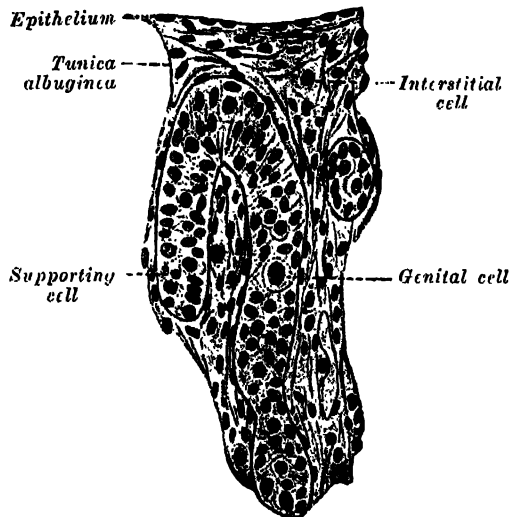
FIG. 231.—Section of the ovary of a newly born child. (Waldeyer.)



a tunica albuginea which intervenes between the testis-cords and the surface epithelium and excludes the latter from any part in the formation of the tissue of the testis. The thin inner ends of the testis-cords converge toward the future hilum and there unite in a network which ultimately becomes the rete testis. From the outer parts of the testis-cords the seminiferous tubules are developed, and between them connective tissue septa extend. The tubules of the rete testis become connected with outgrowths from the Wolffian body, which, as already mentioned, form the efferent ducts of the testis.

Descent of the testes.—The testes, at an early period of foetal life, are placed in the posterior part of the abdominal cavity, and each is attached to the mesonephros by a peritoneal fold, named the *mesorchium*. From the front of the mesonephros a fold of peritoneum, termed the *inguinal fold*, grows forwards to meet and fuse with a peritoneal fold, named the *inguinal crest*, which grows backwards from the anterolateral abdominal wall. The testis thus acquires an indirect connexion with the anterior abdominal wall; and at the same time a portion of the peritoneal cavity lateral to these fused folds is marked off as the future saccus vaginalis. In the inguinal crest a peculiar structure, the *gubernaculum testis*, makes its appearance. This is at first a slender band, extending from that part of the skin

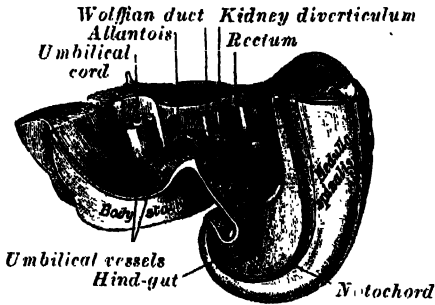
FIG. 232.—Section of a genital cord of the testis of a human embryo 3.5 cm. long. (Felix and Bühler.)



which afterwards forms the scrotum, through the inguinal canal to the body and epididymis of the testis. As development advances, the peritoneum enclosing the gubernaculum forms two folds, one above the testis and the other below it. The

one above the testis is the *plica vascularis*, and contains ultimately the testicular vessels. The one below, the *plica gubernatrix*, contains the lower part of the gubernaculum and ends at the abdominal inguinal ring in a tube of peritoneum, the *saccus vaginalis*, which protrudes down the inguinal canal. By the fifth month the upper part of the gubernaculum has disappeared, while the lower part has become a thick cord, and consists of a central core of unstriated muscle-fibres, and outside this of a firm layer of striped elements, connected with the abdominal wall; as the scrotum develops, the main portion of the lower end of the gubernaculum is carried, with the skin to which it is attached, to the bottom of this pouch. The

FIG. 233.—Tail end of human embryo, from twenty-five to twenty-nine days old. (From model by Keibel.)



saccus vaginalis projects itself downwards into the inguinal canal, and emerges at the subcutaneous inguinal ring, pushing before it a part of the *Obliquus internus* and the aponeurosis of the *Obliquus externus*, which form respectively the *Cremaster* muscle and the *intercrural fascia*. It forms a gradually elongating pouch, which eventually reaches the bottom of the scrotum, and behind this pouch the gubernaculum lies. The testis, being attached by the gubernaculum to the bottom of the scrotum, passes first into the inguinal canal and eventually into the scrotum, invaginating the *saccus vaginalis* from behind. It seems certain also that the gubernacular cord becomes shortened

as development proceeds, and this assists in causing the testis to reach the bottom of the scrotum. By the end of the eighth month the testis has reached the scrotum, and the upper part of the *saccus vaginalis* is converted into a narrow canal which is obliterated a short time after birth, and this obliteration extends gradually downwards to within a short distance of the testis. The lower part of the *saccus vaginalis* is thus entirely cut off from the general peritoneal cavity and constitutes the parietal portion of the *tunica vaginalis*. Sometimes the testes are retained within the abdomen or inguinal canal, constituting what is known as *cryptorchismus*.

Descent of the ovaries.—In the female there is also a gubernaculum, which effects a considerable change in the position of the ovary, though not so extensive as that of the testis. The gubernaculum in the female lies in contact with the fundus of the uterus and contracts adhesions to this organ. The part of the gubernaculum between the ovary and the uterus becomes the ligament of the ovary, the part between the uterus and the *labium majus* the round ligament of the uterus; a pouch of peritoneum analogous to the *saccus vaginalis* in the male accompanies it along the inguinal canal; it is called the *canal of Nuck*. In rare cases the gubernaculum may fail to contract adhesions to the uterus, and then the ovary descends through the inguinal canal into the *labium majus*, and under these circumstances its position resembles that of the testis.

FIG. 234.—Tail end of human embryo, from thirty-two to thirty-three days old. (From model by Keibel.)



The Metanephros and the Permanent Kidney.—The rudiments of the permanent kidneys make their appearance about the end of the first or the beginning of the second month. Each kidney has a twofold origin, part arising from the *metanephros*, and part as a diverticulum from the hind-end of the *Wolffian duct* close to where the latter opens into the cloaca (figs. 233, 234). The *metanephros* arises in the intermediate cell mass, caudal to the *mesonephros* which it resembles in

structure. The diverticulum from the Wolffian duct grows dorsalwards and forwards along the posterior abdominal wall, where its blind extremity expands and subsequently divides into several buds, which form the rudiments of the pelvis and calyces of the kidney; by continued growth and subdivision it gives rise to the collecting tubules of the kidney. The proximal portion of the diverticulum becomes the ureter. The secretory tubules are developed from the metanephros, which is moulded over the growing end of the diverticulum from the Wolffian duct. The tubules of the metanephros, unlike those of the pronephros and mesonephros, do not open into the Wolffian duct. One end of each tubule expands to form a glomerulus, while the rest rapidly elongates to form the convoluted tubule, the loop of Henle, and the junctional tubule; the last joins and establishes communication with one of the collecting tubules which are derived from the ultimate ramifications of the diverticulum from the Wolffian duct. The mesoderm around the tubules is condensed to form the connective tissue of the kidney. The ureter opens at first into the hind-end of the Wolffian duct; after the sixth week it separates from the Wolffian duct, and opens independently into the part of the cloaca which ultimately becomes the bladder (figs. 235, 236).

The secretory tubules of the kidney are arranged into pyramidal masses or lobules, the bases of which are at the surface of the kidney, while their apices constitute the renal papillæ. The lobulated condition of the kidneys exists for some time after birth and traces of it may be found in the adult. The kidneys of the ox and many other animals remain lobulated throughout life.

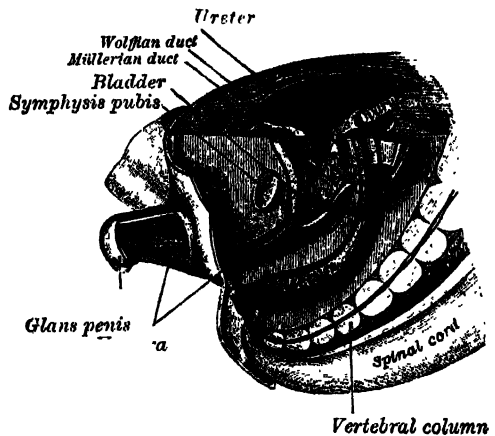
The Urinary Bladder.—The bladder is formed partly from the entodermal cloaca and partly from the ends of the Wolffian ducts; the allantois takes no share in its formation. After the separation of the rectum from the dorsal part of the cloaca (p. 139), the ventral part becomes subdivided into three portions: (1) a dorsal *vesico-urethral portion*, continuous with the allantois—into this portion the Wolffian ducts open; (2) an intermediate narrow channel, the *pelvic portion*; and (3) a ventral, broad *phallic portion*, closed externally by the urogenital membrane (fig. 236). The second and third parts together constitute the *urogenital sinus*. The vesico-urethral portion absorbs the ends of the Wolffian ducts and the associated ends of the renal diverticula, and these give rise to the trigone of the bladder and part of the prostatic urethra. The remainder of the vesico-urethral portion forms the body of the bladder and part of the prostatic urethra; its apex is prolonged to the umbilicus as a narrow canal, which later is obliterated and becomes the medial umbilical ligament (urachus).

The prostate originally consists of two separate portions, each of which arises as a series of buds from the epithelial lining of the urogenital sinus and vesico-urethral part of the cloaca, between the third and fourth months. These buds become tubular, and form the glandular substance of the two lobes which ultimately meet and fuse behind the urethra and also extend on to its ventral aspect. The isthmus or middle lobe is formed as an extension of the lateral lobes between the common ejaculatory ducts and the bladder. *Skene's ducts* in the female urethra are regarded as the homologues of the prostatic glands.

The *bulbo-urethral glands of Cowper* in the male, and *greater vestibular glands of Bartholin* in the female, also arise as diverticula from the epithelial lining of the urogenital sinus.

The External Organs of Generation (fig. 237).—As already stated (p. 139), the cloacal membrane, composed of ectoderm and entoderm, originally reaches from the umbilicus to the tail. The mesoderm extends to the midventral line for some

FIG. 235.—Tail end of human embryo, from eight and a half to nine weeks old. (From model by Keibel.)

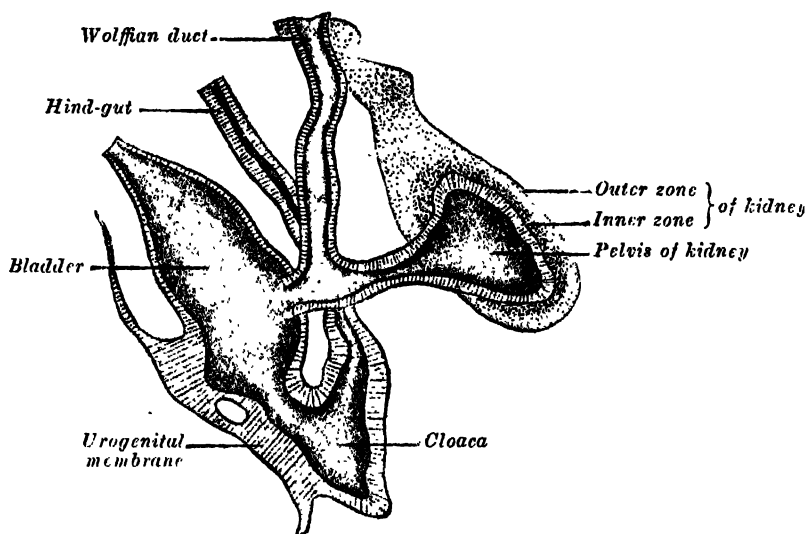


distance behind the umbilicus, and forms the lower part of the abdominal wall; it ends below in a prominent swelling, the *cloacal tubercle*. Behind this tubercle the urogenital part of the cloacal membrane separates the ingrowing sheets of mesoderm.

The first rudiment of the penis (or clitoris) is a structure termed the *phallus*; it is derived from the phallic portion of the cloaca which has extended on to the end and sides of the under surface of the cloacal tubercle. The terminal part of the phallus, representing the future glans penis, becomes solid; the remainder, which is hollow, is converted into a longitudinal groove by the absorption of the urogenital membrane.

In the female a deep groove forms around the phallus and separates it from the rest of the cloacal tubercle, which is now termed the *genital tubercle*. The sides of the genital tubercle grow backwards as the *genital swellings*, which ultimately form the labia majora; the tubercle itself becomes the mons pubis. The labia minora arise by the continued growth of the lips of the groove on the under surface of the phallus; the remainder of the phallus forms the clitoris.

FIG. 236.—Primitive kidney and bladder, from a reconstruction. (After Schreiner.)
(From Quain's Elements of Anatomy, vol. i., Embryology.)



In the male the early changes are similar, but the pelvic portion of the cloaca undergoes much greater development, pushing before it the phallic portion. The genital swellings extend round between the pelvic portion and the anus, and form a scrotal area; during the changes associated with the descent of the testes this area is drawn out to form the scrotal sacs. The penis is developed from the phallus. As in the female, the urogenital membrane undergoes absorption, forming a channel on the under surface of the phallus; this channel extends only as far forwards as the corona glandis.

The corpora cavernosa of the penis (or clitoris) and of the urethra arise from the mesodermal tissue in the phallus; they are at first dense structures, but later vascular spaces appear in them, and they gradually become cavernous.

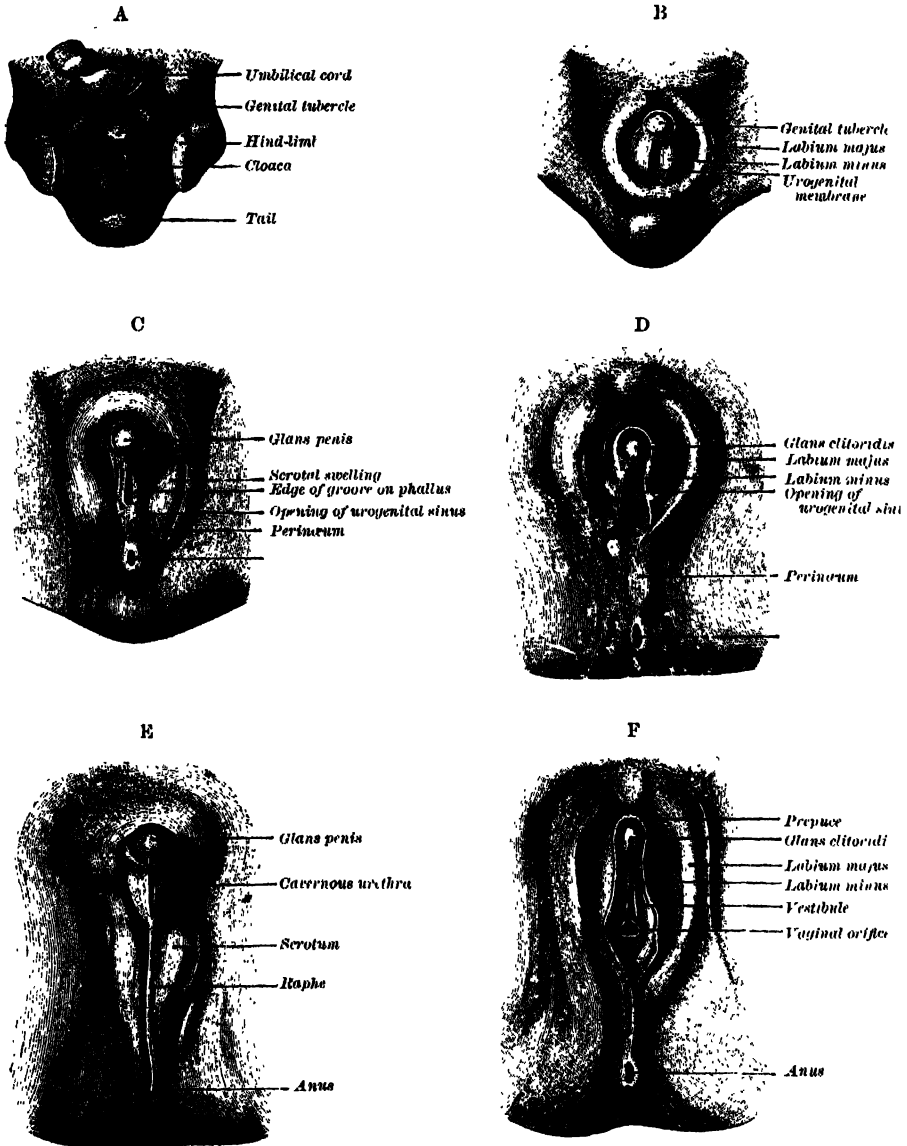
The *prepuce* is formed by the growth of a solid plate of ectoderm into the superficial part of the phallus; on coronal section this plate presents the shape of a horseshoe. By the breaking down of its more centrally situated cells the plate is split into two lamellæ, and a cutaneous fold, the prepuce, is liberated and forms a hood over the glans. 'Adherent prepuce is not an adhesion really, but a hindered central desquamation' (Berry Hart, *op. cit.*).

The Urethra.—As already described, in both sexes the phallic portion of the cloaca extends on to the under surface of the cloacal tubercle as far forwards as the apex. At the apex the walls of the phallic portion come together and fuse, the lumen is obliterated, and a solid plate, the *urethral plate*, is formed. The remainder

of the phallic portion is for a time tubular, and then, by the absorption of the urogenital membrane, it establishes a communication with the exterior; this opening is the *primitive urogenital ostium*, and it extends forwards to the corona glandis.

In the female this condition is largely retained; the portion of the groove on the clitoris broadens out while the body of the clitoris enlarges, and thus the adult urethral opening is situated behind the base of the clitoris.

FIG. 237.—Stages in the development of the external sexual organs in the male and female. (From the Ecker-Ziegler models.)

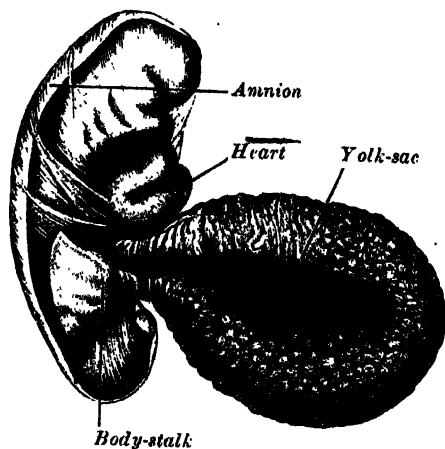


In the male, by the greater growth of the pelvic portion of the cloaca a longer urethra is formed, and the primitive ostium is carried forwards with the phallus, but it still ends at the corona glandis. Later the groove closes from behind forwards. Meanwhile the urethral plate of the glans breaks down centrally to form a median groove continuous with the primitive ostium. This groove also closes from behind forwards, so that the external urethral opening is shifted forwards to the end of the glans penis.

THE FORM OF THE EMBRYO AT DIFFERENT STAGES OF ITS GROWTH.

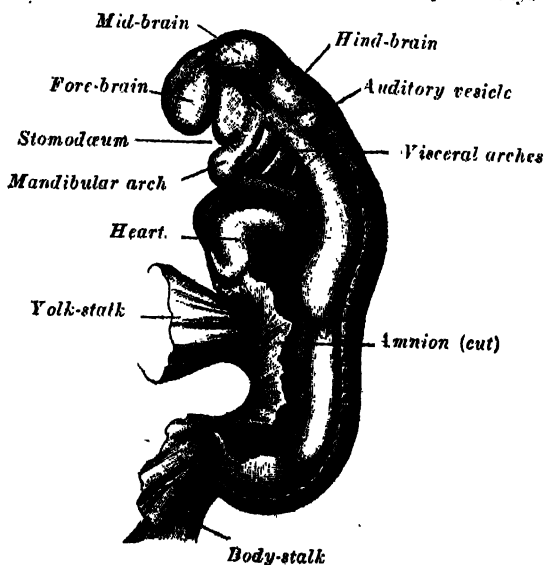
First Week.—During the first week the ovum is in the uterine tube. Having been fertilised in the upper part of the tube, it passes slowly down, undergoing segmentation, reaches the uterus. Peters* described a specimen, the age of which he reckoned

FIG. 238.—Human embryo 2.6 mm. long. (His.)



as from three to four days. It was imbedded in the decidua on the posterior wall of the uterus and enveloped by a decidua capsularis, the central part of which, however, consisted merely of a layer of fibrin. The ovum was in the form of a sac, the outer wall of which consisted of a layer of trophoblast; inside this was a thin layer of mesoderm composed of round, oval, and spindle-shaped cells. Numerous villous processes—some consisting of trophoblast only, others possessing a core of mesoderm—

FIG. 239.—Human embryo between eighteen and twenty-one days old. (His.)



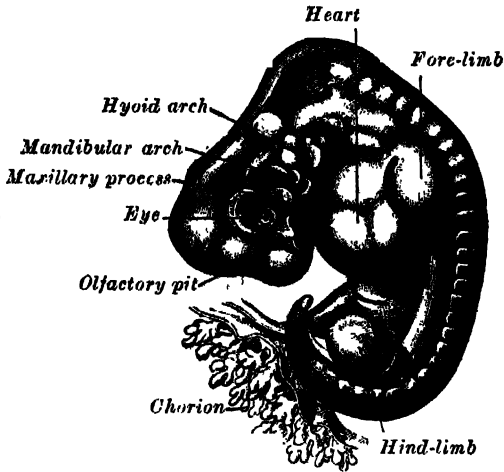
projected from the surface of the ovum into the surrounding decidua. Inside this sac the rudiment of the embryo was found in the form of a patch of ectoderm, covered by a small but completely closed amnion. It possessed a minute archenteron and

* Peters, *Die Einbettung des menschlichen Eies*, 1899.

was surrounded by mesoderm, which was connected by a band to that lining the trophoblast (fig. 94).*

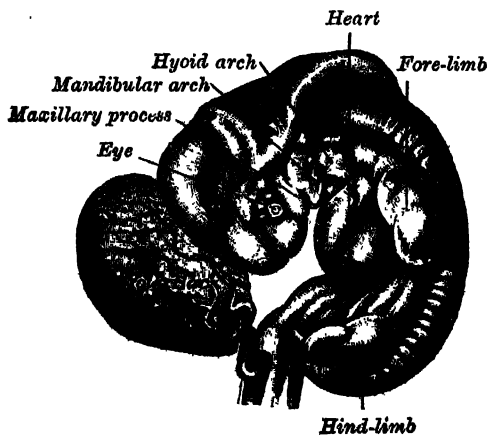
Second Week.—By the end of this week the ovum has increased considerably in size, and the majority of its villi are vascularised. The embryo has assumed a definite form, and its cephalic and caudal extremities are easily distinguished. The neural folds are partly united. The embryo is more completely separated from the yolk-sac, and the paraxial mesoderm is being divided into the primitive segments (fig. 238.)

FIG. 240.—Human embryo, between twenty-seven and thirty days old (His.)



Third Week.—By the end of the third week the embryo is strongly curved, and the primitive segments number about thirty. The primary divisions of the brain are visible, and the optic and auditory vesicles are formed. Four branchial grooves are present; the stomodæum is well marked, and the buccopharyngeal membrane has disappeared. The rudiments of the limbs are seen as short buds, and the Wolffian bodies are visible (fig. 239).

FIG. 241.—Human embryo, between thirty-one and thirty-four days old. (His.)



Fourth Week.—The embryo is markedly curved on itself, and when viewed in profile is almost circular in outline. The cerebral hemispheres appear as hollow buds, and the elevations which form the rudiments of the auricula are visible. The limbs now appear as oval flattened projections (fig. 240).

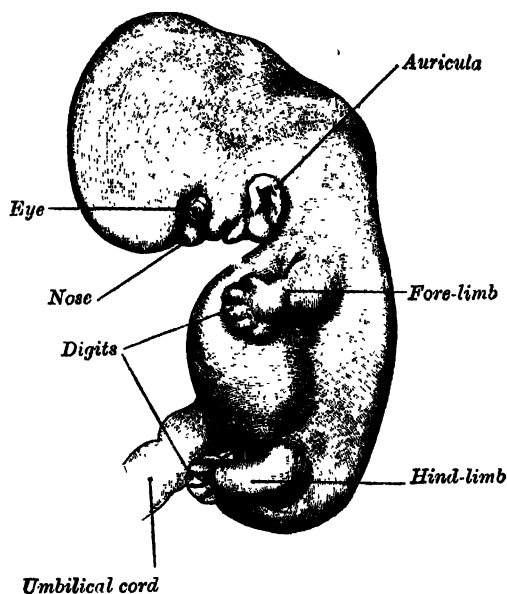
* Bryce and Teacher (*Early Development and Imbedding of the Human Ovum*, 1908) are of opinion that the age of Peters' ovum has been understated.

Fifth Week.—The embryo is less curved and the head is relatively of large size. Differentiation of the limbs into their segments occurs. The nose forms a short, flattened projection. The cloacal tubercle is evident (fig. 241).

Sixth Week.—The curvature of the embryo is further diminished. The branchial grooves—except the first—have disappeared, and the rudiments of the fingers and toes can be recognised (fig. 242).

Seventh and Eighth Weeks.—The flexure of the head is gradually reduced and the neck is somewhat lengthened. The upper lip is completed and the nose is more prominent. The nostrils are directed forwards and the palate is not completely developed. The eyelids are present in the shape of folds above and below the eye, and the different parts of the auricle are distinguishable. By the end of the second month the fœtus measures from 28 to 30 mm. in length (fig. 243).

FIG. 242.—Human embryo about six weeks old. (Hlis.)



Third Month.—The head is extended and the neck is lengthened. The eyelids meet and fuse, remaining closed until the end of the sixth month. The limbs are well developed and nails appear on the digits. The external generative organs are so far differentiated that it is possible to distinguish the sex. By the end of this month the length of the fœtus is about 7 cm., but if the legs be included it is from 9 to 10 cm.

Fourth Month.—The loop of gut which projected into the umbilical cord is withdrawn within the fœtus. The hairs begin to make their appearance. There is a general increase in size, so that by the end of the fourth month the fœtus measures 12 to 13 cm. in length, but if the legs be included it is from 16 to 20 cm.

Fifth Month.—It is during the fifth month that the first movements of the fœtus are usually observed. The eruption of hair on the head commences, and the vernix caseosa begins to be deposited. By the end of this month the total length of the fœtus, including the legs, is from 25 to 27 cm.

Sixth Month.—The body is covered by fine hairs (*lanugo*) and the deposit of vernix caseosa is considerable. The papillæ of the skin are developed and the free borders of the nails project from the corium of the dermis. Measured from vertex to heels, the total length of the fœtus at the end of this month is from 30 to 32 cm.

Seventh Month.—The pupillary membrane atrophies and the eyelids are open. The testis descends with the vaginal sac of the peritoneum. From vertex to heels the total length at the end of the seventh month is from 35 to 36 cm. The weight is about 1·5 kilograms.

Eighth Month.—The skin assumes a pink colour and is now entirely coated with vernix caseosa, and the lanugo begins to disappear. Subcutaneous fat has been developed to a considerable extent, and the foetus presents a plump appearance. The total length, i.e. from head to heels, at the end of the eighth month is about 40 cm., and the weight varies between 2 and 2·5 kilograms.

FIG. 243.—Human embryo about eight and a half weeks old. (His.)



Ninth Month.—The lanugo has largely disappeared from the trunk. The umbilicus is almost in the middle of the body and the testes are in the scrotum. At full time the foetus weighs from 3 to 3·5 kilograms, and measures from head to heels about 50 cm.

OSTEOLOGY

THE general framework of the body is built up mainly of a series of bones supplemented in certain regions by pieces of cartilage; this bony and cartilaginous framework constitutes the *skeleton*.

In comparative anatomy the term skeleton has a wider application, since in some of the lower animals hard, protecting and supporting structures are developed in association with the integumentary system. In such animals the skeleton consists of an internal or deep skeleton, the *endoskeleton*; and an external or superficial, the *exoskeleton*. In the human subject the exoskeleton is very rudimentary, its only important representatives being the nails and the enamel of the teeth, and the term skeleton is, therefore, confined to the endoskeleton; this is divisible into an *axial* part, which includes the bones of the head and trunk, and an *appendicular* part, which comprises those of the extremities or limbs. The minute structure and the physical properties of bones are described on pages 17 to 24.

In the skeleton of the adult there are 206 bones, grouped as follows:—

Axial Skeleton	{	Vertebral column	26	
	{	Skull	22	
	{	Hyoid bone	1	
	{	Ribs and sternum	25	
			—	74
Appendicular Skeleton	{	Upper extremities	64	
	{	Lower extremities	62	
			—	126
		Auditory ossicles		6
			—	
		Total		206

Bones are divisible into four classes: *long*, *short*, *flat*, and *irregular*.

The **long bones** are found in the limbs, where they form levers; each consists of a body or shaft and two extremities. The *body* or *diaphysis* is cylindrical, with a central cavity termed the *medullary cavity*; the wall surrounding the cavity consists of dense, compact substance of considerable thickness in the middle part of the body, but becoming thinner towards the extremities; projecting into the medullary cavity is some spongy substance, scanty in the middle of the body, but plentiful towards the ends. The *extremities* are usually expanded, for purposes of articulation and muscular attachment; they consist of spongy substance surrounded by compact bone, and are usually developed from one or more separate centres of ossification termed *epiphyses*. The medullary cavity and the spaces in the spongy substance are filled with marrow (*medulla ossium*).

Short bones.—Where a part of the skeleton is intended for strength and compactness combined with limited movement, it is constructed of a number of short bones, as in the *carpus* and *tarsus*. These consist of spongy substance covered by a thin crust of compact bone.

Flat bones.—Where the principal requirement of the skeleton is to protect delicate structures, or provide broad surfaces for muscular attachment, the bones are expanded into plates, as in the skull and the scapula, and are composed of two thin layers of compact bone separated by a variable quantity of spongy

substance. In the cranial bones, the layers of compact bone are familiarly known as the *tables* of the skull; the outer table is thick and tough, the inner thin, dense, and brittle. The intervening spongy substance is called the *diploe*, and this, in certain regions of the skull, undergoes absorption, and spaces filled with air (*air-sinuses*) are left between the two tables of the skull.

The irregular bones, from their peculiar form, cannot be grouped under the preceding heads. They consist of spongy substance enclosed within a thin layer of compact bone.

Surfaces of bones.—On the surfaces of the bones are eminences and depressions, either articular or non-articular. *Articular eminences* are seen in the heads of the humerus and femur; and *articular depressions* in the glenoid cavity of the scapula, and the acetabulum of the hip-bone. *Non-articular eminences* are designated according to their form. Thus, a broad, rough, uneven elevation is called a *tuberosity*, *trochanter*, *protuberance*, or *process*; a small, rough prominence, a *tubercle*; a sharp, slender, pointed eminence, a *spine*; a narrow, rough elevation of some length, a *ridge*, *crest*, or *line*. *Non-articular depressions* are also of variable form, and are described as *fossæ*, *pits*, *depressions*, *grooves*, *furrows*, *fissures*, *notches*, &c

THE VERTEBRAL COLUMN (COLUMNA VERTEBRALIS)

The vertebral column is a flexuous and flexible column, formed of a series of bones called *vertebræ*. These are thirty-three in number, and are grouped under the names *cervical*, *thoracic*, *lumbar*, *sacral*, and *coccygeal* according to the regions they occupy; there are seven vertebræ in the cervical region, twelve in the thoracic, five in the lumbar, five in the sacral, and four in the coccygeal.

The cervical, thoracic, and lumbar vertebra remain separate from one another throughout life, and are therefore known as *true* or *movable* vertebræ; the sacral and coccygeal vertebræ, on the other hand, are termed *false* or *fixed* vertebræ, because they are united in the adult to form two bones, viz. the *sacrum* and *coccyx*, formed respectively by the fused sacral and coccygeal vertebræ.

GENERAL CHARACTERISTICS OF A VERTEBRA

With the exception of the first and second cervical, the true or movable vertebræ present certain common characteristics which are best studied by examining one from the middle of the thoracic region.

A typical vertebra (fig. 244) consists of two principal parts, an anterior, the *body*, and a posterior, the *vertebral arch*, these enclose a foramen, the *vertebral foramen*.

In the articulated vertebral column the bodies form a pillar for the support of the head and trunk, and the vertebral foramina constitute a canal in which the medulla spinalis or spinal cord is lodged and protected. Between every pair of vertebræ are two *intervertebral foramina* one on either side, for the transmission of the spinal nerves and vessels.

The body of a vertebra is more or less cylindrical in shape; its upper and lower surfaces are flattened and rough, and give attachment to the intervertebral fibrocartilages, and each presents a rim around its circumference. In front, it is convex from side to side and concave from above downwards; behind, it is slightly concave from side to side and flat from above downwards. On its anterior surface are a few small apertures for the passage of nutrient vessels; on its posterior surface is a large, irregular aperture (occasionally more than one) for the exit of the basivertebral veins from the body of the vertebra.

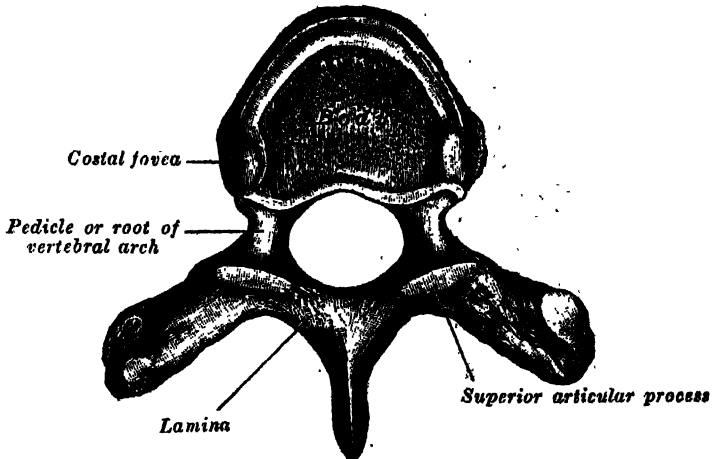
The *vertebral arch* consists of a pair of *pedicles* or *roots* and a pair of *laminae*; it supports seven *processes*, viz. four *articular*, two *transverse* and one *spinous*.

The *pedicles*, or *roots of the vertebral arches*, are short, thick processes, which project backwards, one on either side, from the body, at the

junction of its posterior and lateral surfaces. The concavities above and below the pedicles are named the *vertebral notches*; and when the vertebrae are articulated with one another, the notches of each contiguous pair of bones form the *intervertebral foramina*, already referred to.

The laminae are two broad plates directed backwards and medialwards from the pedicles. They fuse in the middle line posteriorly, and so complete

FIG. 244.—A typical thoracic vertebra, viewed from above.



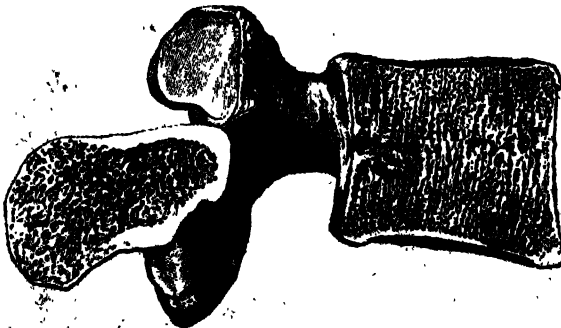
the posterior boundary of the vertebral foramen. Their upper borders and the lower parts of their anterior surfaces are rough for the attachment of the *ligamenta flava*.

The spinous process is directed backwards and downwards from the junction of the laminae, and serves for the attachment of muscles and ligaments.

The articular processes, two superior and two inferior, spring from the junctions of the pedicles and laminae. The superior processes project upwards, and their articular surfaces are directed more or less backwards; the inferior project downwards, and their surfaces look more or less forwards.

The transverse processes project lateralwards from the points where the laminae join the pedicles; they serve for the attachment of muscles and ligaments.

FIG. 245.—Sagittal section of a lumbar vertebra.



Structure of a vertebra (fig. 245).—The body is composed of spongy substance covered by a thin coating of compact bone; the latter is perforated by numerous orifices for the passage of vessels; the interior of the body is traversed by one of two large canals, for the reception of veins, which converge towards the large

aperture on the posterior surface of the body. The vertebral arch and the processes projecting from it have thick coverings of compact substance.

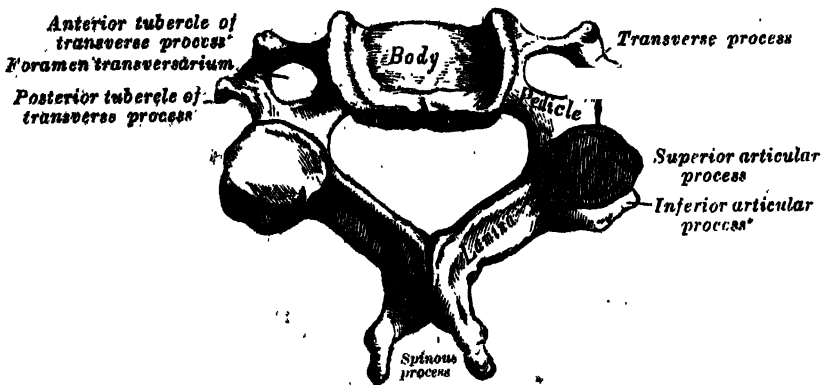
CERVICAL VERTEBRÆ (VERTEBRÆ CERVICALES)

The cervical vertebrae (figs. 246, 247), seven in number, are the smallest of the true vertebrae, and can be readily distinguished from the thoracic or lumbar vertebrae by the presence of a foramen in each transverse process.

The first, second, and seventh cervical vertebrae present exceptional features; the following characteristics are common to the remaining four.

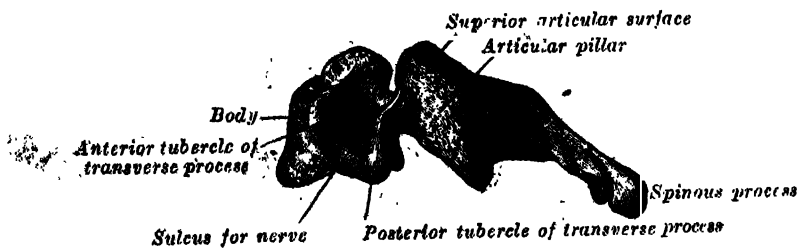
The *body* is small, and broader from side to side than from before backwards. The anterior and posterior surfaces are flattened and of equal depth, but the anterior is placed on a lower level than the posterior, and its inferior border is prolonged downwards, so as to overlap the upper and front part of the succeeding vertebra. The superior surface is concave transversely, and presents an

FIG. 246.—A typical cervical vertebra, from above.



upwardly projecting lip on either side; the inferior surface is saddle-shaped, i.e. concave from before backwards, convex from side to side, and presents laterally shallow concavities which receive the projecting lips of the subjacent vertebra. The *pedicles* are directed lateralwards and backwards, and are attached to the body midway between its upper and lower borders, so that the superior and inferior vertebral notches are of equal depth; the superior notch is, however, narrower than the inferior. The *laminae* are narrow, and thinner above than below; the *vertebral foramen* is large, and of triangular form. The *spinous process* is short and bifid, the two parts being often of unequal size. The *superior* and *inferior articular processes* on either side are fused to form an *articular pillar*, which projects lateralwards from the junction of the pedicle

FIG. 247.—Side view of a typical cervical vertebra.



and lamina. The articular facets are flat and of an oval form; the superior look backwards, upwards, and slightly medialwards; the inferior forwards, downwards, and slightly lateralwards. In the third and fourth vertebrae the lateral surfaces of the articular pillars are grooved for the accommodation of the medial branches of the posterior divisions of the corresponding cervical nerves. The *transverse processes* are each pierced by the *foramen transversarium*, which, in the upper six vertebrae, gives passage to

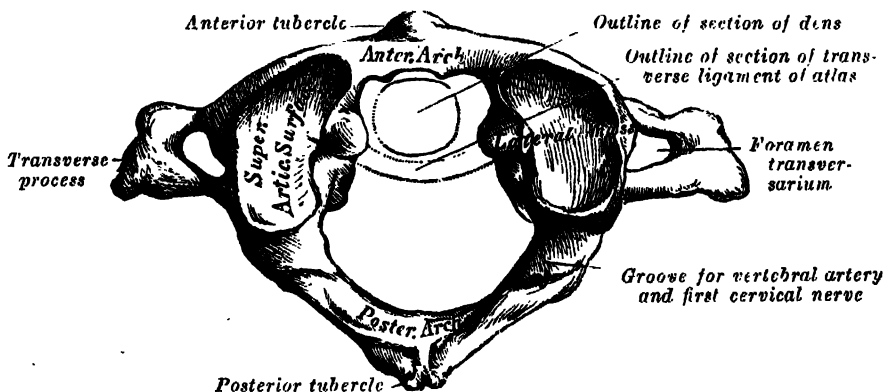
* Some markings on the cervical vertebrae. Wood Jones, *Journal of Anatomy and Physiology*, 1911.

the vertebral artery and vein and a plexus of sympathetic nerves. Each process consists of an anterior and a posterior part. The anterior portion is the homologue of the rib in the thoracic region, and is therefore named the *costal process*; it arises from the side of the body, is directed lateralwards in front of the foramen, and ends in a tubercle, the *tuberculum anterius*. The posterior part, the true transverse process, springs from the vertebral arch behind the foramen transversarium, and is directed forwards and lateralwards; it ends in a flattened vertical tubercle, the *tuberculum posterius*. Lateral to the foramen transversarium the anterior and posterior tubercles are united by a curved bar of bone, the concavity or sulcus on the upper surface of which accommodates the anterior division of the corresponding spinal nerve. This sulcus is deeper, wider, and more downwardly directed in the fifth and sixth than in the third and fourth vertebrae.*

Chassaignac pointed out that the common carotid artery can be compressed against the anterior tubercle of the transverse process of the sixth cervical vertebra; this tubercle therefore is named the *tuberculum caroticum* or *Chassaignac's tubercle*. It also constitutes an important guide to the vertebral artery.

The first cervical vertebra (fig. 248) is named the atlas because it supports the globe of the head. Its chief peculiarity is that it has no body, and

FIG. 248.—First cervical vertebra, or atlas, from above.



this is due to the fact that the body of the atlas has fused with that of the second vertebra. It has no spinous process but is ring-like, and consists of an anterior and a posterior arch and two lateral masses. The *anterior arch* forms about one-fifth of the ring: its front surface is convex, and at its centre is the *anterior tubercle* for the attachment of parts of the Longus colli muscles; posteriorly it is concave, and marked by a smooth, oval or circular facet (fovea dentis), for articulation with the dens or odontoid process of the epistropheus or axis. The upper and lower borders respectively give attachment to the anterior atlanto-occipital membrane and the anterior atlanto-epistropheal ligament; the former connects the atlas with the occipital bone, the latter with the epistropheus. The *posterior arch* forms about two-fifths of the ring: at the centre of its posterior surface is the *posterior tubercle*, which is the rudiment of a spinous process and gives origin to the Recti capitis posteriores minores. The small size of this process prevents it from interfering with the movements between the atlas and the skull. The upper edge of the central part of the posterior arch is rounded and affords attachment to the posterior atlanto-occipital membrane, while immediately behind the superior articular process of each lateral mass is a groove, the *sulcus arteriæ vertebralis*, sometimes converted into a foramen by a bony spiculum which arches backwards from the posterior end of the

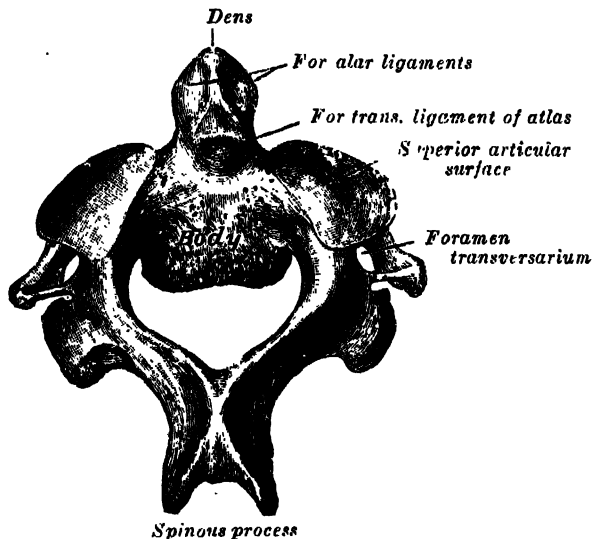
* The *costal element* of a cervical vertebra not only includes the portion which springs from the side of the body, but the anterior and posterior tubercles and the bar of bone which connects the latter (fig. 107).

superior articular process. This sulcus transmits the vertebral artery, which, after ascending through the foramen in the transverse process, winds round the lateral mass in a direction backwards and medialwards; it also transmits the suboccipital or first spinal nerve. On the under surface of the posterior arch, behind the articular facets, are the two shallow inferior vertebral notches. The lower border of the posterior arch gives attachment to the posterior atlanto-epistropheal ligament.

The *lateral masses* support the weight of the head; each carries two articular facets, a superior and an inferior. The superior facets are of large size, oval, concave, and approach each other in front, but diverge behind; they are directed upwards, medialwards, and a little backwards, and form cups for the reception of the condyles of the occipital bone, and are admirably adapted to the nodding movements of the head; occasionally they are constricted near their centres. Just below the medial margin of each superior facet is a small tubercle, for the attachment of the transverse ligament of the atlas; this ligament divides the ring of the atlas into two unequal parts—the anterior or smaller part receiving the dens or odontoid process of the epistropheus, the posterior transmitting the medulla spinalis and its membranes. The inferior articular facets are nearly circular in form, flattened or slightly convex and directed downwards and medialwards, articulating with the epistropheus, and permitting the rotatory movements of the head. The *transverse processes* are long and project lateralwards and downwards from the lateral masses; their anterior and posterior tubercles are fused into one mass. The foramen transversarium is large and is directed upwards and backwards.

The second cervical vertebra or epistropheus (axis) (figs. 249, 250) forms the pivot upon which the atlas, carrying the head, rotates. The chief

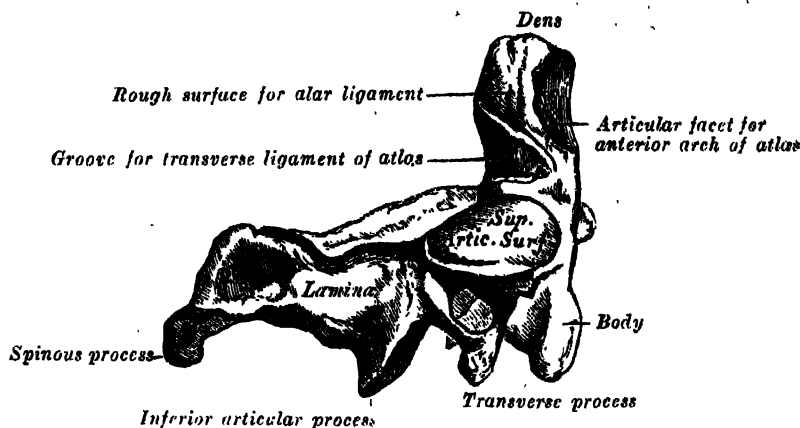
FIG. 249.—Second cervical vertebra, or epistropheus, from above.



characteristic of this bone is the strong tooth-like process, the *dens*, which projects perpendicularly from the upper surface of the body. The *body* is deeper in front than behind. On its anterior surface is a median ridge, separating two depressions for the attachment of the Longus colli muscles. Its under surface is concave from before backwards and convex from side to side. The *dens* (odontoid process) is about 1.5 cm. long, and exhibits a slight constriction, or neck, where it joins the body. On its anterior surface is an oval or nearly circular facet for articulation with that on the posterior surface of the anterior arch of the atlas. On the back of the neck, and frequently extending on to its lateral surfaces, is a shallow groove for the transverse ligament of the atlas, which retains the dens in position. The apex is pointed, and gives attachment to the *ligamentum apicis dentis*; below the apex, the process is somewhat enlarged and presents on either side a rough impression for the attachment of the lateral alar ligaments which connect the dens to the occipital bone. The internal structure of the dens is more compact than that of the body. The *pedicles* are broad and strong, especially in front, where they fuse with the sides of the body and the root of the dens. They are covered above by the superior articular surfaces. The *laminae* are thick and strong, and the vertebral foramen large but smaller than that of the atlas. The *transverse processes* are very small; each ends in a single tubercle and is perforated

by the foramen transversarium which is directed upwards and lateralwards. The *superior articular surfaces* are circular, slightly convex, directed upwards and slightly lateralwards, and are supported on the body, pedicles, and transverse processes; the *inferior* have the same direction as those of the typical cervical vertebrae. The *superior vertebral notches* are very shallow, and lie behind the articular processes; the *inferior* lie in front of the articular processes,

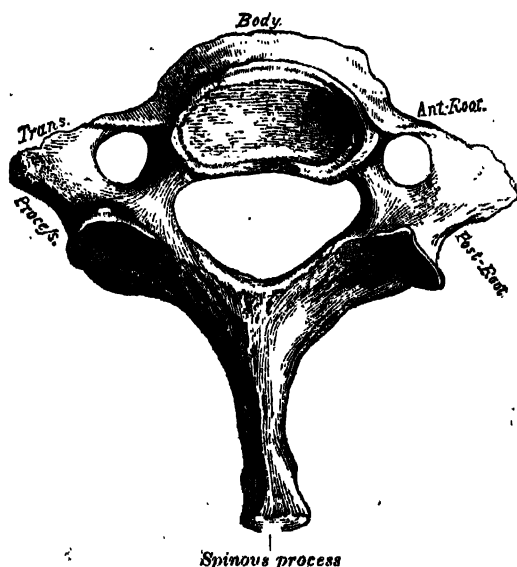
FIG. 250.—Second cervical vertebra, or epistropheus, from the side.



as in the typical cervical vertebrae. The *spinous process* is large and very strong; it is deeply channelled on its under surface, and has a bifid, tuberculated extremity.

The *seventh cervical vertebra* (fig. 251).—This vertebra is named the *vertebra prominens* because of its long and prominent spinous process. This process is thick, and nearly horizontal in direction; it is not bifurcated, but ends in a tubercle to which the lower end of the ligamentum nuchæ is attached.

FIG. 251.—Seventh cervical vertebra, from above.



The *transverse processes* are of considerable size; their posterior roots are large and prominent, the anterior small and faintly marked; the upper surface of each process has usually a shallow sulcus for the seventh cervical nerve, and the extremity of the process seldom presents more than a trace of division. The superior articular facets look almost directly backwards. The foramen transversarium is generally smaller than that in the other cervical vertebrae; rarely it is double, sometimes it is absent. On the left side it occasionally gives passage to the vertebral artery; sometimes the vertebral vein traverses it on both sides; but as a rule the artery

and vein pass in front of the transverse process. Occasionally the anterior roots of the transverse processes of this vertebra exist as separate bones, which extend lateralwards and forwards, and are known as *cervical ribs*.

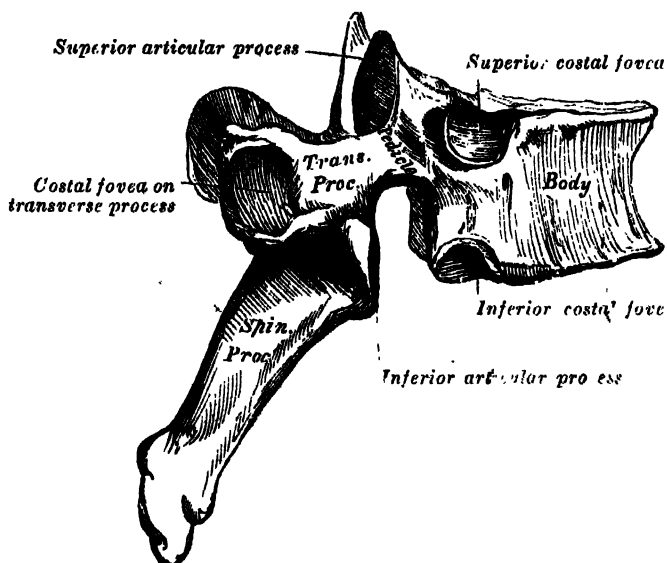
THORACIC VERTEBRÆ (VERTEBRÆ THORACALES)

The thoracic vertebræ (fig. 252), twelve in number, increase in size from above downwards. All are distinguished by the presence of foveæ or facets on the sides of the bodies for articulation with the heads of the ribs; and all, except the eleventh and twelfth, by facets on the transverse processes, for articulation with the tubercles of the ribs.

The first, ninth, tenth, eleventh, and twelfth thoracic vertebræ present certain peculiarities, and must be specially considered (fig. 253).

In the middle part of the thoracic region the bodies are heart-shaped, and their anteroposterior and transverse diameters are about equal, but at the upper and lower ends of the region they resemble respectively those of the cervical and lumbar vertebræ. They are slightly thicker behind than in front, flat above and below, convex from side to side in front, deeply concave behind,

FIG. 252.—A typical thoracic vertebra, from the side.

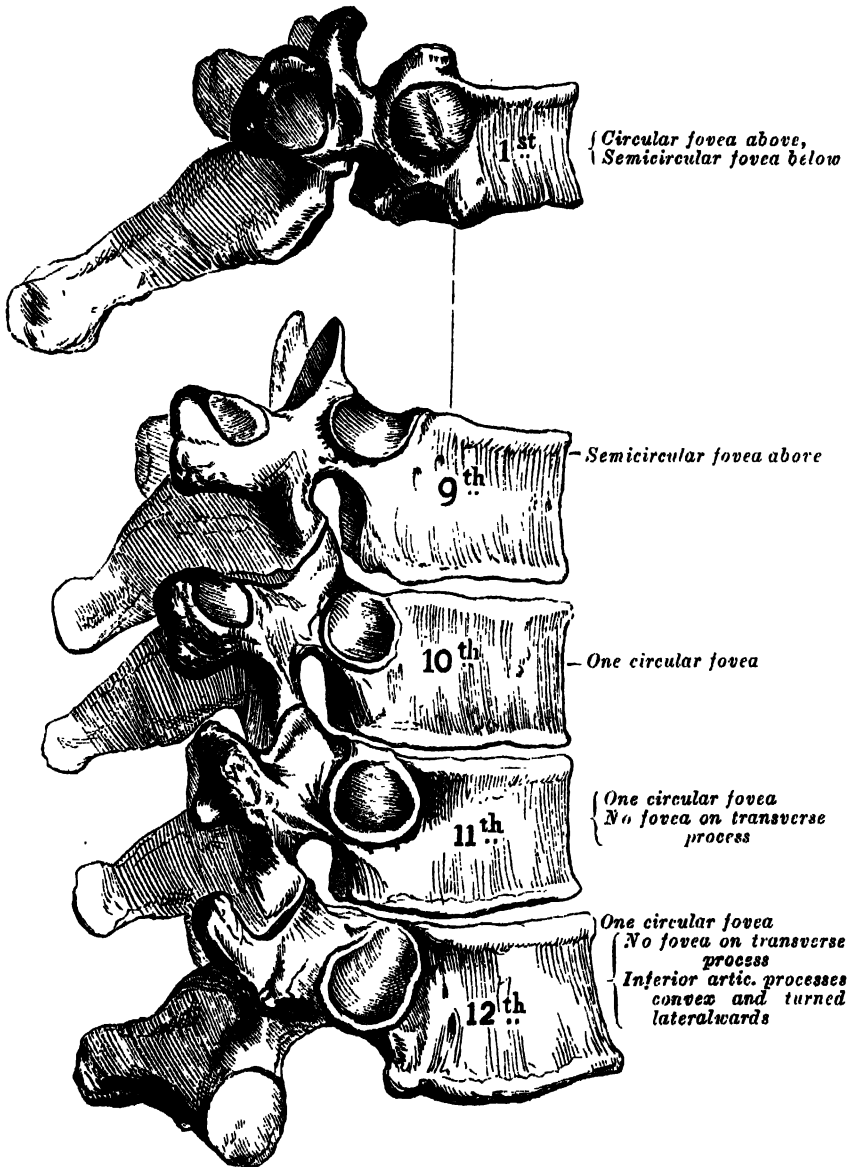


and slightly constricted laterally and in front. They present on either side, two costal foveæ or facets, a superior near the root of the pedicle, and an inferior in front of the inferior vertebral notch; in the articulated vertebral column these foveæ form, with the intervertebral fibrocartilages, oval surfaces for the reception of the heads of the ribs. The *pedicles* are directed backwards and slightly upwards, and the inferior vertebral notches are of large size, and deeper than in the cervical or lumbar vertebræ. The *laminae* are broad, thick, and overlap those of subjacent vertebræ like tiles on a roof. The *vertebral foramen* is smaller than that of the cervical or lumbar vertebræ, and is of a circular form. The *spinous process* is long, triangular on coronal section, directed obliquely downwards, and ends in a tuberculated extremity. These processes overlap from the fifth to the eighth, but are less oblique in direction above and below these levels.* The *superior articular processes* are thin plates of bone projecting upwards from the junctions of the pedicles and laminae; their articular facets are almost flat, and are directed backwards and a little lateralwards and upwards. The *inferior articular processes* are fused to a considerable extent with the laminae, and project but slightly beyond their lower borders; their facets are

* In quadrupeds the majority of the spinous processes of the thoracic vertebræ project upwards and backwards, while those of the lumbar region are directed upwards and forwards. The change in inclination is effected in one of the lower thoracic vertebræ, the spine of which points almost directly upwards. This vertebra is known as the *anticlinal*, and in man its representative is the eleventh thoracic.

directed forwards and a little medialwards and downwards. The *transverse processes* arise from the arch behind the superior articular processes and pedicles; they are thick, strong, and of considerable length, directed obliquely backwards and lateralwards, and each ends in a clubbed extremity, on the front of which is a small costal fovea or facet, for articulation with the tubercle of a rib. In

FIG. 253.—Peculiar thoracic vertebræ.



the upper six thoracic vertebræ the costal foveæ are concave, and are placed on the anterior surfaces of the transverse processes; in the vertebræ from the seventh to the tenth inclusive the costal foveæ are flat and placed on the upper margin of the transverse processes.

The first thoracic vertebra has on either side of the upper part of the body a complete fovea for the head of the first rib, and at the lower part of the body a small fovea for the upper half of the head of the second rib. The body resembles that of the seventh cervical vertebra, being broad transversely,

while its upper surface is concave in the same direction, and lipped on either side. The *superior articular surfaces* are directed upwards and backwards; the *spinous process* is thick, long, and almost horizontal. The *transverse processes* are long, and the superior vertebral notches are deeper than those of the other thoracic vertebræ.

The ninth thoracic vertebra may have no inferior costal foveæ, but in some cases these are present.

The tenth thoracic vertebra has usually a complete costal fovea, placed partly on the lateral surface of the pedicle, for the head of the tenth rib, but the fovea for the head of this rib is sometimes completed by the body of the ninth vertebra.

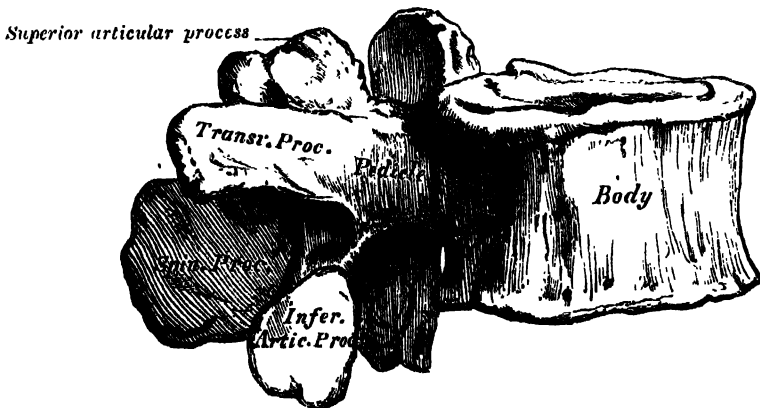
In the eleventh thoracic vertebra the *body* approaches in form and size those of the lumbar vertebræ. The *foveæ* for the heads of the ribs are large, and placed chiefly on the pedicles, which are thicker and stronger in this and the next vertebra than in any other part of the thoracic region. The *spinous process* is short, and nearly horizontal in direction. The *transverse processes* are very short, tuberculated at their extremities, and have no costal foveæ.

The twelfth thoracic vertebra has the same general characteristics as the eleventh, but may be distinguished from it by its inferior articular surfaces being convex and directed lateralwards, like those of the lumbar vertebræ; by the body, laminae, and spinous process, which resemble those of lumbar vertebræ; and by each transverse process being a short irregular knob subdivided into superior, inferior, and lateral tubercles: the superior and inferior tubercles correspond to the mamillary and accessory processes of the lumbar vertebræ. Traces of similar tubercles are found on the transverse processes of the tenth and eleventh thoracic vertebræ.

LUMBAR VERTEBRÆ (VERTEBRÆ LUMBALES)

The lumbar vertebræ (figs. 254, 255), five in number, are the largest segments of the movable part of the vertebral column, and can be distinguished

FIG. 254.—A lumbar vertebra, from the side.

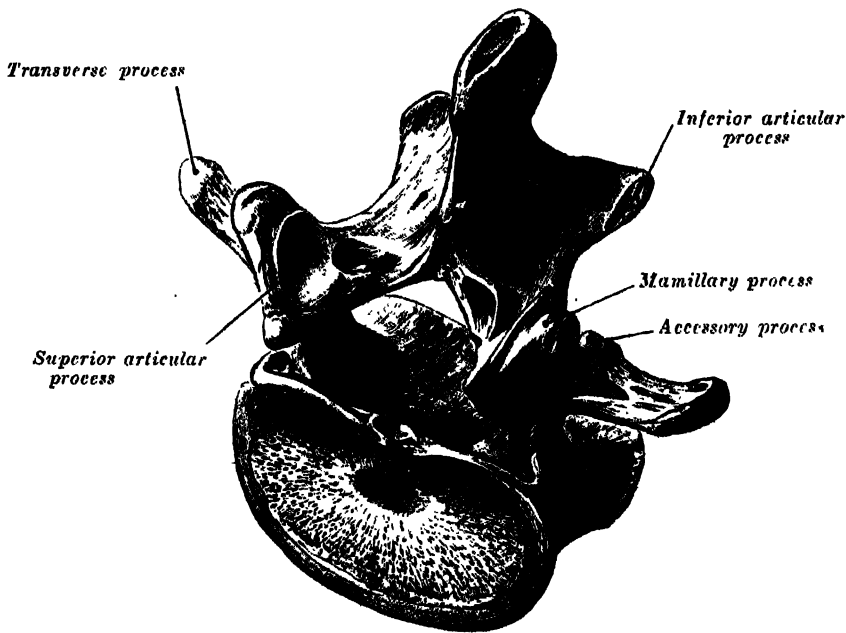


by the absence of foramina in their transverse processes, and of costal foveæ on the sides of the bodies.

The *body* is large, wider from side to side than from before backwards, and a little thicker in front than behind. It is flattened above and below, concave behind, and constricted in front, and at the sides. The *pedicles* are strong, and directed backwards from the upper part of the body; consequently, the inferior vertebral notches are of considerable depth. The *laminae* are broad, short, and strong; the *vertebral foramen* is triangular, larger than in the thoracic, but

smaller than in the cervical region. The *spinous process* is thick, broad, and somewhat quadrilateral; it projects backwards and ends in a rough, uneven border. The *superior* and *inferior articular processes* project respectively upwards and downwards from the junctions of pedicles and laminae. The facets on the superior processes are concave, and look backwards and medialwards; those on the inferior are convex, and are directed forwards and lateralwards. The superior articular processes are wider apart than the inferior, since in the articulated column the inferior articular processes are embraced by the superior processes of the subjacent vertebra. The *transverse processes* are situated in front of the articular processes instead of behind them as in the thoracic vertebrae, and are homologous with the ribs. Those of the upper three vertebrae arise from the junctions of the pedicles and laminae, and are long, slender, and horizontally directed; those of the lower two vertebrae incline a little upwards and spring from the pedicles and posterior parts of the bodies.

FIG. 255.—A lumbar vertebra, from above and behind.



The transverse process of the first lumbar vertebra is sometimes developed as a separate piece which may remain permanently ununited with the rest of the bone, thus forming a lumbar rib. Of the tubercles noticed in connexion with the transverse processes of the lower thoracic vertebrae, the *superior* is connected in the lumbar region with the posterior part of the superior articular process, and is named the *mamillary process*; the *inferior* is situated at the posterior part of the base of the transverse process, and is called the *accessory process* (fig. 255).*

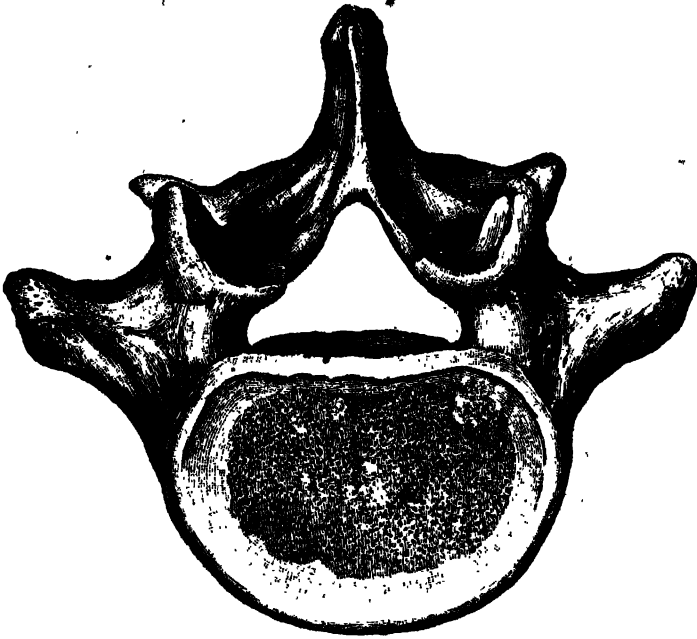
The fifth lumbar vertebra (fig. 256) is characterised by its body being considerably deeper in front than behind, a condition which accords with the prominence of the sacrovertebral articulation; by the small size of its spinous process; by the wide interval between the inferior articular processes; and by the thickness of its transverse processes, which spring from the body as well as from the pedicles.

* The mamillary and accessory processes are merely muscular processes which, represented and conjoined in the thoracic region, become separated in the lumbar region by the passage of the internal branch of the posterior division of the lower thoracic and lumbar nerves between them. (Wood-Jones, *Journal of Anatomy and Physiology*, vol. xlvii., p. 118.)

THE SACRUM (Os SACRUM)

The sacrum is a large, triangular bone formed by the fusion of the five sacral vertebrae. It is situated in the lower part of the vertebral column and at the upper and posterior part of the pelvic cavity, where it is inserted like a wedge between the two hip-bones; its upper part or base articulates with the fifth lumbar vertebra, its apex with the coccyx. It is rather narrower at the level of the second vertebra than at the level of the third. It is curved longitudinally, and placed very obliquely, its base projecting forwards and forming the prominent *sacrovertebral angle* when articulated with the last lumbar vertebra; the central part of the bone is projected backwards, so as to give increased capacity to the pelvic cavity. The sacrum has a pelvic, a dorsal, and two lateral surfaces, a base, an apex, and a central canal.

Fig. 256.—Fifth lumbar vertebra, from above.



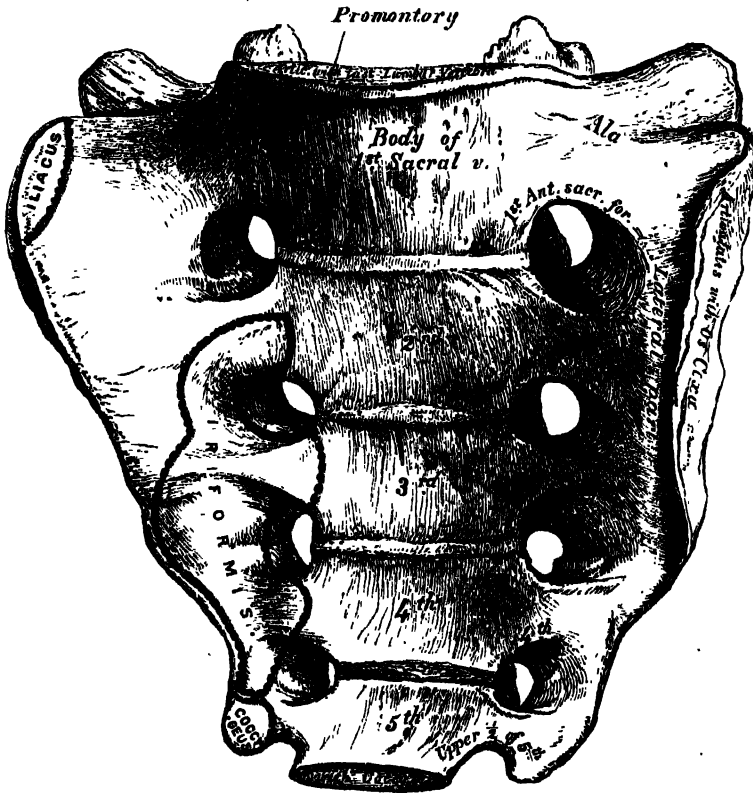
The *pelvic surface* (fig. 257) is concave from above downwards, and slightly so from side to side. Its middle part is crossed by four transverse ridges, which correspond in position with the original planes of separation between the five segments of the bone; the portions between the ridges are the bodies of the sacral vertebrae. The body of the first segment is of large size, and in form resembles that of a lumbar vertebra; the succeeding ones diminish from above downwards, are flattened from before backwards, and curved to accommodate themselves to the form of the sacrum, being concave in front, and convex behind. Lateral to the ridges are the four *anterior sacral foramina*, somewhat rounded in form, diminishing in size from above downwards, and directed lateralwards and forwards: they open into the sacral canal and give exit to the anterior divisions of the sacral nerves, and entrance to the lateral *sacral arteries*. Lateral to these foramina are the *lateral parts* of the sacrum, each consisting of five separate segments at an early period of life; in the adult, these are blended with the bodies and with each other. Each lateral part is traversed by four broad, shallow grooves, which lodge the anterior divisions of the sacral nerves, and are separated from one another by prominent ridges of bone which give origin to the *Piriformis*.

If a sagittal section be made through the centre of the sacrum (fig. 261), the bodies are seen to be united at their circumferences by bone, wide intervals

being left centrally, which, in the recent state, are filled by the intervertebral fibrocartilages. In some specimens the union is more complete between the lower than between the upper segments.

The *dorsal surface* (fig. 258) is convex and narrower than the pelvic. In the middle line is the *medial sacral crest*, surmounted by the rudimentary spinous processes of the upper three or four sacral vertebrae. On either side of this crest is the *sacral groove*, which gives origin to the Multifidus, the floor of the groove being formed by the united laminae of the vertebrae. The laminae of the fifth sacral vertebra, and sometimes those of the fourth, fail to meet behind, and thus a deficiency (*hiatus sacralis*) occurs in the posterior wall of the sacral canal. Lateral to each sacral groove is a linear series of tubercles produced by the fusion of the articular processes which together form the

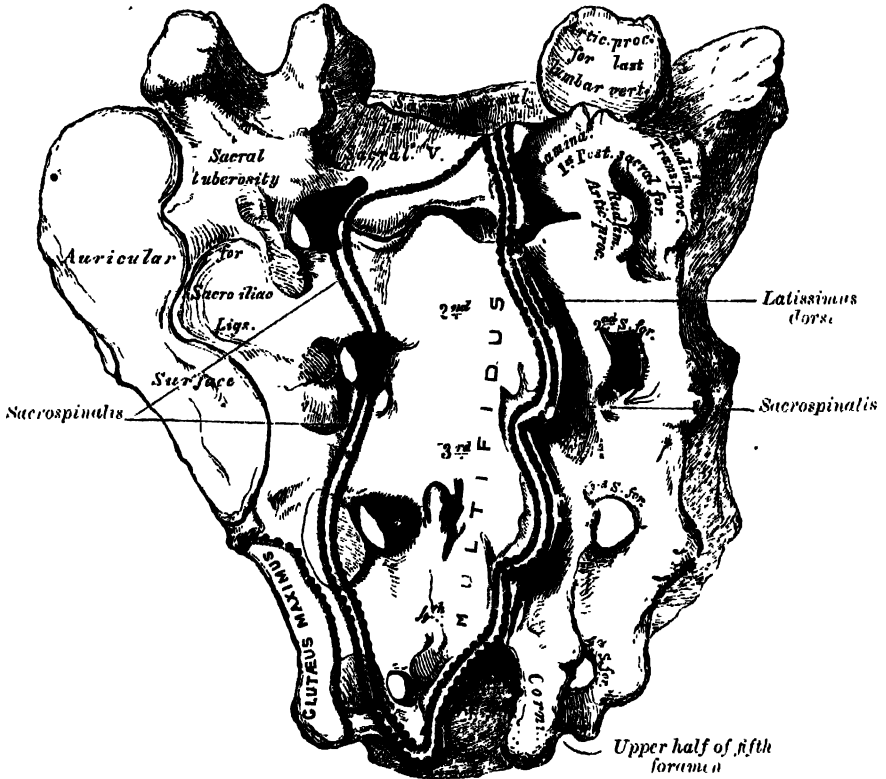
FIG. 257.—Sacrum, pelvic surface.



indistinct *sacral articular crests*. The articular processes of the first sacral vertebra are large; their facets are oval or circular in shape, and are concave from side to side; they look backwards and medialwards, and articulate with the facets on the inferior processes of the fifth lumbar vertebra. The tubercles which represent the inferior articular processes of the fifth sacral vertebra are prolonged downwards as rounded processes, which are named the *sacral cornua*, and are connected to the cornua of the coccyx. Lateral to the sacral articular crests are the four *posterior sacral foramina*; they are smaller in size and less regular in form than the anterior foramina, and transmit the posterior divisions of the sacral nerves. Lateral to the posterior sacral foramina are the *lateral sacral crests*, formed by the fused transverse processes of the sacral vertebrae. The transverse tubercles of the first sacral vertebra are large and very distinct; they and the transverse tubercles of the second vertebra, give attachment to the short posterior sacro-iliac ligaments; those of the third vertebra give attachment to the long posterior sacro-iliac ligaments; and those of the fourth and fifth to the sacrotuberous ligaments.

The *lateral surface* (fig. 259) is broad above, but narrowed into a thin edge below. On the upper part is an ear-shaped surface, the *auricular surface*, for articulation with the ilium; behind this is a rough area, the *sacral tuberosity*, on which are three deep impressions, for the attachment of the posterior sacroiliac ligament. The thin, lower part of the lateral surface gives attachment to the sacrotuberous and sacrospinous ligaments, to some fibres of the *Glutæus maximus* behind, and to the *Coccygeus* in front. It ends below in a projection called the *inferior lateral angle*; the notch on the medial side of this angle is converted into a foramen by the transverse process of the first piece of the coccyx, and transmits the anterior division of the fifth sacral nerve.

FIG. 258.—Sacrum, dorsal surface.



The *base* of the sacrum (fig. 260) is transversely expanded, and is directed upwards and forwards; it somewhat resembles the upper surface of the last lumbar vertebra. In the middle is the large oval upper surface of the body of the first sacral vertebra, which is connected with the under surface of the body of the last lumbar vertebra by an intervertebral fibrocartilage; the anterior projecting edge of the body is named the *promontory*. Behind the body is the superior orifice of the sacral canal, triangular in shape and completed posteriorly by the arch of the first sacral vertebra. On either side of the body is a large triangular plate called the *ala sacralis*; its upper surface is slightly concave from side to side, convex from before backwards, and in the articulated pelvis is continuous with the iliac fossa. The posterior third of the ala represents the transverse process, and the anterior two-thirds, the costal process of the first sacral vertebra. The superior articular processes are attached to the body of the first sacral vertebra and to the alæ by short thick pedicles; they are oval, concave, directed backwards and medialwards, like the superior articular processes of the lumbar vertebrae. On the upper surface of each pedicle is a vertebral notch, which forms the lower part of the foramen between the last lumbar and first sacral vertebrae.

FIG. 259.—Lateral surfaces of sacrum and cœcyx.

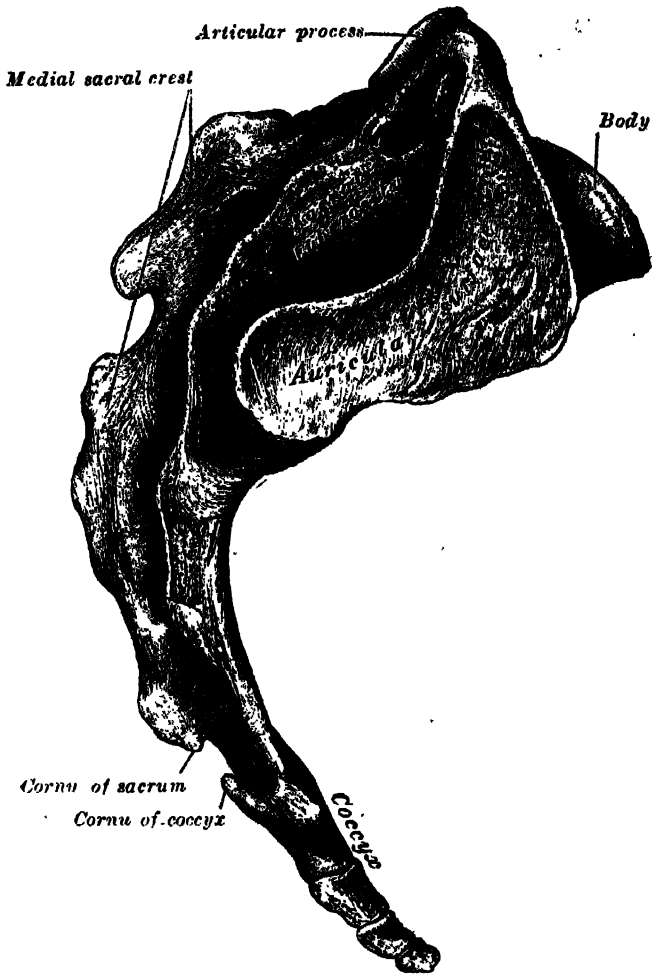
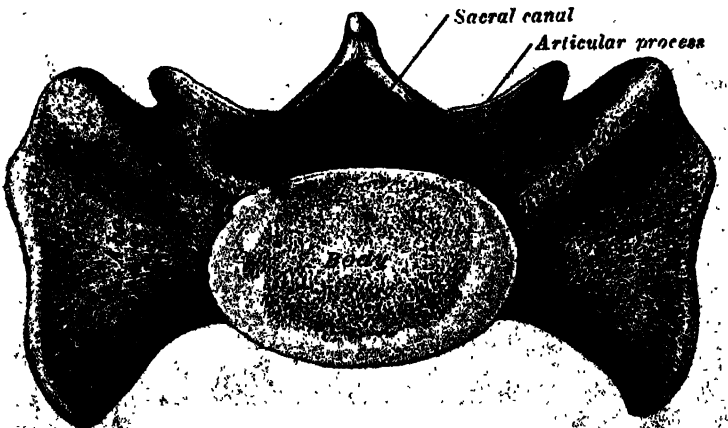


FIG. 260.—Base of sacrum.



arches. At birth the vertebra consists of three pieces, viz. the body and the halves of the vertebral arch. During the first year the halves of the arch unite behind, the union taking place first in the lumbar region and then extending upwards through the thoracic and cervical regions. In the upper cervical vertebrae the bodies unite with the arches about the third year; in the lower lumbar vertebrae union is not completed until the sixth year. Until puberty, the upper and under surfaces of the bodies and the ends of the transverse and spinous processes are cartilaginous, but about the sixteenth year (fig. 265) five secondary centres appear, one for the tip of each transverse process, one for the end of the spinous process, one each for the circumferential parts of the upper and lower surfaces of the body (fig. 266). These fuse with the rest of the bone about the age of twenty-five. In the bifid spines of the cervical vertebrae there are two secondary centres.

Exceptions to this mode of development occur in the first, second, and seventh cervical vertebrae, and in the lumbar vertebrae.

The atlas or first cervical vertebra, is usually ossified from three centres (fig. 267). One appears in each lateral mass about the seventh week of foetal life, and gradually extends into the posterior arch, where they unite between the third and fourth years, either directly or through the medium of a separate centre. At birth, the anterior arch consists of cartilage; in this a separate centre appears about the end of the first year, and unites with the lateral masses between the sixth and eighth years—the lines of union extending across the anterior portions of the superior articular facets. Occasionally the anterior arch is formed by the forward extension and ultimate union of the two lateral masses; sometimes it is ossified from two laterally placed centres.

The epistropheus, or second cervical vertebra, is ossified from five primary and two secondary centres (fig. 268). The vertebral arch is ossified from two centres,

FIG. 264.—Ossification of a vertebra.

By 3 primary centres

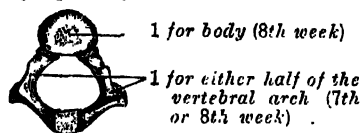


FIG. 265.

By 3 secondary centres

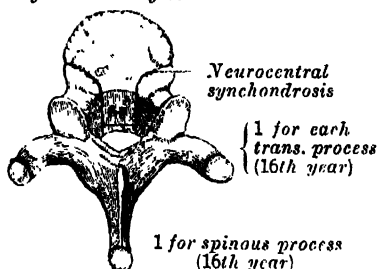


FIG. 266.

By 2 additional

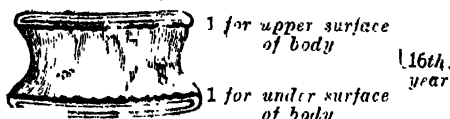


FIG. 267.—Atlas.

By 3 centres

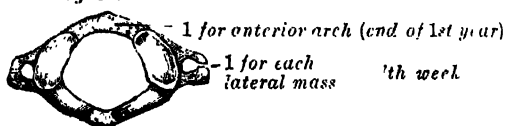


FIG. 268.—Epistropheus.

By 7 centres

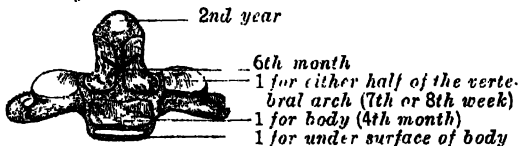
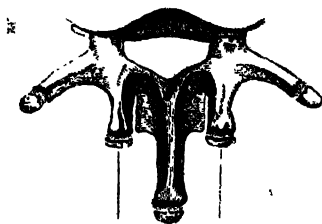


FIG. 269.—Lumbar vertebra.



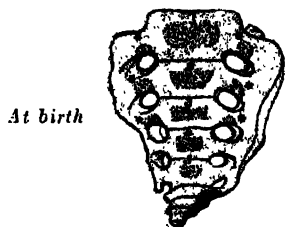
2 additional centres for mamillary processes

Exceptional cases

and the body from one, as in a typical vertebra; the centres for the vertebral arch appear about the seventh or eighth week of foetal life, that for the body about

FIG. 270.—Ossification of the sacrum.

*Additional centres
for costal elements**



At birth

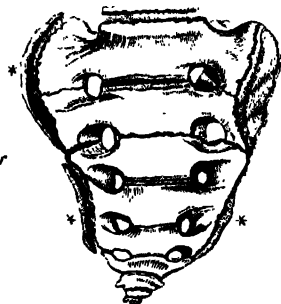
FIG. 271.



*At
4 1/2 years*

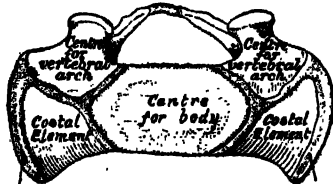
FIG. 272.

*Two epiphysial plates for each lateral
surface**



*At
25th year*

FIG. 273.—Base of sacrum of adolescent



Lateral epiphysis

Lateral epiphysis

the fourth or fifth month. About the sixth month of foetal life, two laterally placed centres appear in the base of the dens or odontoid process, and join before birth to form a conical mass, deeply cleft above. A wedge-shaped piece of cartilage fills the cleft and forms the summit of the process; in this a centre appears about the second year and unites with the main mass about the twelfth year. The base of the dens is separated from the body of the epistropheus by a cartilaginous disc, the circumference of which ossifies, but the centre remains cartilaginous until advanced age. In this cartilage, rudiments of the lower epiphysial lamella of the atlas and the upper epiphysial lamella of the epistropheus may sometimes be found. In addition to these there is a centre for a thin epiphysial plate on the under surface of the body of the bone.

The seventh cervical vertebra.—The costal processes of this vertebra are usually ossified from separate centres which appear about the sixth month of foetal life, and join the body and transverse processes between the fifth and sixth years. As already stated (p. 166), the costal processes may persist as separate pieces, and grow lateralwards and forwards, to constitute cervical ribs.

Separate ossific centres have also been found in the costal processes of the fourth, fifth, and sixth cervical vertebrae.

The lumbar vertebrae (fig. 269) have each two additional centres, for the mamillary processes.

Sacrum (figs. 270 to 273).—Each sacral vertebra is ossified from three primary centres, one for the body and two for the vertebral arch. Two epiphysial plates are ossified for each body, one for the upper and the other for the lower surface.

The anterior portions of the lateral parts of the sacrum have six additional (costal) centres, two for each of the first three vertebrae; these appear above and lateral to the anterior sacral foramina (figs. 270*, 271).

Two epiphysial plates are developed on each lateral surface of the sacrum (fig. 272*, 273); one for the auricular surface, and another for the thin edge of bone below this surface.†

† The ends of the spinous processes of the upper three sacral vertebrae are sometimes developed from separate epiphyses, and Fawcett (*Anatomischer Anzeiger*, 1907, Bd. xxx.) has pointed out that a number of epiphyses may be seen in the sacrum at the age of eighteen years. These are distributed as follows: One for each of the two mamillary processes of the first sacral vertebra; twelve—six on either side—in connexion with the costal elements (two each for the first and second and one each for the third and fourth vertebrae); and eight for the transverse processes—four on either side—one each for the first, third, fourth, and fifth. He is further of opinion that the lower part of each lateral surface of the sacrum is formed by the extension and union of the costal epiphyses of the third and fourth segments and the 'transverse' epiphyses of the fourth and fifth segments.

Periods of ossification.—Ossification commences in the bodies of the sacral vertebrae as follows: in the first about the eighth or ninth week of foetal life; in the second about the tenth week; and in the fourth and fifth between the fifth and eighth months. About the twelfth week of foetal life the vertebral arch of the first segment begins to ossify; and after the sixth month the costal centres for the lateral parts of the bone make their appearance. In the lower vertebrae the arches fuse with the bodies in the second year; in the first vertebra fusion does not occur until the fifth or sixth year. About the sixteenth year the epiphysal plates for the upper and under surfaces of the bodies are formed; and between the eighteenth and twentieth years those for the lateral surfaces of the bone make their appearance. During early life, the bodies of the sacral vertebrae are separated from each other by intervertebral fibrocartilages, but about the eighteenth year the bodies of the two lower vertebrae become united by bone, and the process of bony union gradually extends upwards, with the result that between the twenty-fifth and thirtieth years of life all the vertebrae are united (fig. 261).

Coccyx.—Each segment of the coccyx is ossified from one centre. The centres appear in the following order: in the first segment between the first and fourth years; in the second between the fifth and tenth years; in the third between the tenth and fifteenth years; in the fourth between the fourteenth and twentieth years. A secondary centre for each sacral cornu, and a pair of epiphysal plates for each of the rudimentary bodies have been described. As age advances, the segments unite with one another, the union between the first and second being frequently delayed until after the age of twenty-five or thirty years. At a late period of life, especially in females, the coccyx often fuses with the sacrum.

VERTEBRAL COLUMN AS A WHOLE

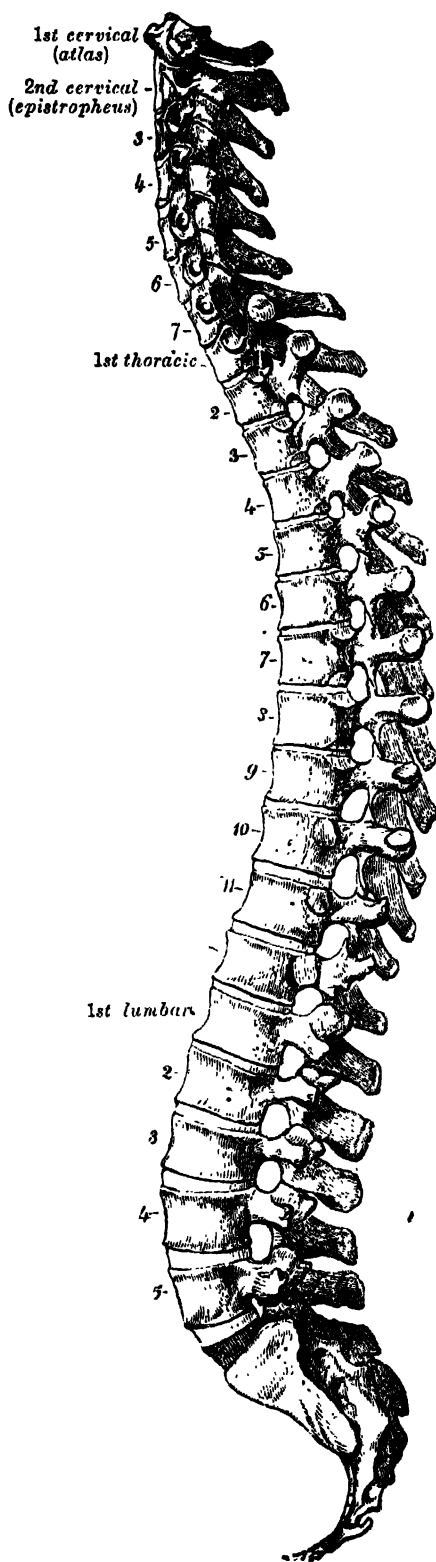
The vertebral column is situated in the median line, at the posterior part of the trunk. Its average length in the male is about 71 cm.; of this the cervical part measures 12·5 cm., the thoracic 28 cm., the lumbar 18 cm., and the sacrum and coccyx 12·5 cm. The average length of the female column is about 61 cm.

Curves.—Viewed laterally (fig. 274), the vertebral column presents cervical, thoracic, lumbar, and pelvic curves. The thoracic and pelvic curves are termed primary curves, because they alone are present during foetal life. The cervical and lumbar curves are compensatory or secondary, and are developed after birth, the cervical curve when the child is able to hold up its head (at three or four months), and to sit upright (about nine months), the lumbar at twelve or eighteen months when the child begins to walk. The cervical curve is convex forwards, and is the least marked of the four; it begins at the atlas, and ends at the middle of the second thoracic vertebra. The thoracic curve, concave forwards, extends from the middle of the second to the middle of the twelfth thoracic vertebra. The lumbar curve is convex anteriorly and is more pronounced in the female than in the male. It reaches from the middle of the last thoracic vertebra to the sacrovertebral angle, and the convexity of the lower three segments is greater than that of the upper two. The pelvic curve extends from the sacrovertebral articulation to the apex of the coccyx; its concavity is directed downwards and forwards.

In the upper part of the thoracic region of the vertebral column there is a slight lateral curvature, with its convexity directed towards the right side in right-handed persons. Some regard this curve as being due to the greater use and muscularity of the right arm, and in support of this explanation it has been found that in left-handed individuals the convexity of the curve is directed towards the left side. Others regard it as being produced by the aortic arch and upper part of the descending thoracic aorta—a view which is supported by the fact that in cases where the viscera are transposed and the aorta is consequently on the right side, the convexity of the curve is directed to the left.

Anterior surface.—When viewed from in front, the width of the bodies of the vertebrae is seen to increase from the second cervical to the first thoracic; there is then a slight diminution in the next three vertebrae; below this

FIG. 274.—Lateral view of the vertebral column.



there is again a gradual and progressive increase in width as low as the sacrovertebral angle. From this point there is a rapid diminution, to the apex of the coccyx.

The *posterior surface* of the vertebral column presents in the median line the spinous processes. In the cervical region (with the exception of the second and seventh vertebræ) these are short and horizontal, with bifid extremities. In the upper part of the thoracic region they are directed obliquely downwards; in the middle part they are almost vertical; in the lower part of the thoracic region, and in the lumbar region they are nearly horizontal. They are separated by considerable intervals in the cervical and lumbar regions, but are closely approximated in the middle of the thoracic region. Occasionally one of these processes deviates from the median line—a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the vertebral column. On either side of the spinous processes is the *vertebral groove* formed by the laminae in the cervical and lumbar regions, where it is shallow, and by the laminae and transverse processes in the thoracic region, where it is deep and broad; these grooves lodge the deep muscles of the back. Lateral to the vertebral grooves are the articular processes, and still more laterally the transverse processes. In the thoracic region, the transverse processes stand backwards, on a plane considerably behind that of the same processes in the cervical and lumbar regions. In the cervical region, the transverse processes are placed in front of the articular processes, laterally to the pedicles and between the intervertebral foramina. In the thoracic region they are posterior to the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are in front of the articular processes, and behind the intervertebral foramina.

The *lateral surfaces* are separated from the posterior surface by the articular processes in the cervical and lumbar regions, and by the transverse processes in the thoracic region. In front are the sides of the bodies of the vertebræ, marked in the thoracic region by the foveæ

for articulation with the heads of the ribs. Between the pedicles are the intervertebral foramina, oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar. These foramina transmit the spinal nerves and vessels, and are situated between the transverse processes in the cervical region, and in front of the transverse processes in the thoracic and lumbar regions.

The *base* of that portion of the vertebral column which is made up of the twenty-four movable vertebræ is formed by the under surface of the body of the fifth lumbar vertebra; and the *summit*, by the upper surface of the atlas.

The *vertebral canal* follows the different curves of the column; it is large and triangular in the cervical and lumbar regions, where movement is free, and is small and rounded in the thoracic region, where motion is more limited.

Applied Anatomy.—Occasionally the coalescence of the laminae is not completed, and consequently a cleft is left in the arches of the vertebræ, through which a protrusion of the spinal membranes (dura mater and arachnoid), and generally of the medulla spinalis and pia mater, takes place, constituting the malformation known as *spina bifida*. This condition is most common in the lumbosacral region, but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain incomplete.

The movable part of the vertebral column being constructed of a number of pieces, securely connected together and enjoying only a slight degree of movement between any two individual pieces, but permitting of a very considerable range as a whole, allows a sufficient degree of mobility without any material diminution of strength. The many joints of which the column is composed, together with the very varied movements to which it is subjected, render it liable to sprains; but, so closely are the individual vertebræ articulated that these sprains are rarely severe, and an amount of violence sufficiently great to produce tearing of the ligaments would tend rather to cause a dislocation or fracture. The further safety of the column and its slight liability to injury are provided for by its disposition in curves instead of in a straight line. For it is an elastic column, and must bend before it breaks; under these circumstances, being made up of three curves, it represents three columns, and greater force is required to produce bending of a short column than of a longer one of equal breadth and similar material. Again, the safety of the column is largely provided for by the presence between the bodies of the intervertebral fibrocartilages, which act as buffers in counteracting the effects of violent jars or shocks.

Fracture-dislocation of the vertebral column may be caused by direct or indirect violence. Fractures from indirect violence are the more common, and here the bodies of the vertebræ are compressed, while the arches are torn asunder; in fracture from direct violence, on the other hand, the arches are compressed and the bodies of the vertebræ separated from each other. It will therefore be seen that in both classes of injury the medulla spinalis is the part least likely to be injured, and may escape damage even where there has been considerable lesion of the bony framework. When a fracture-dislocation is produced by indirect violence, the displacement is almost always the same—the upper segment being driven forwards on the lower, so that the medulla spinalis is compressed between the body of the vertebra below and the arch of the vertebra above.

Lateral curvature of the vertebral column is a common affection in girls who are outgrowing their strength and who sit or stand long at lessons, and is due to the uneven transmission of weight down the column. In addition to the lateral displacement of the spinous processes there is a marked rotation of the bodies of the vertebræ, the displacement of which is far in excess of that of the spinous processes. When the curve is severe and the bones have actually become distorted, the condition is past cure.

Kyphosis is an affection in which there is an increase in the normal thoracic curve, and is due to bending forwards of the upper part of the body carrying the weight of the head. It is seen in rickety children, in rapidly growing adolescents, in senile conditions, and in certain diseases, such as osteo-arthritis and osteitis deformans. In the senile kyphosis often met with in aged labourers, the head is firmly fixed and bent forwards and downwards on to the chest, and the vertebral column is curved and rigid. The ribs are immobilised, the chest is flattened antero-posteriorly, and breathing becomes almost entirely abdominal. *Post mortem*, bony ankylosis of the ligaments and capsules of the intervertebral joints is found, with ossification of the ligamenta flava, interspinal and other ligaments.

It may be noted that in marked cases of spinal deformity the trachea and aorta follow closely along the line of a spinal curvature occurring in their vicinity, whereas the oesophagus between the tracheal bifurcation and the stomach often passes like a bowstring across the concavity of the curve.

Lordosis, on the other hand, is an exaggeration of the normal lumbar curve, the trunk being thrown backwards. This is always a compensatory curve, and occurs when, from

any cause such as pregnancy or tumours, the abdomen is enlarged. It is more strongly marked in cases of disease of the hip-joint where the joint is permanently retained in a flexed position; so that in order to bring the foot down to the ground the pelvis has to be tilted forwards, and this is accomplished by an increase of the normal lumbar curve.

Laminectomy.—The operation of laminectomy is performed in cases of pressure on the medulla spinalis, where the continuity of the nerve-tracts has not been completely destroyed. It consists of cutting down on and removing the laminae and spinous processes in the affected region, so as to relieve the medulla spinalis from pressure; but it is useless in cases of complete destruction of this structure. Laminectomy is chiefly performed (i) for fracture-dislocation; (ii) for localised pressure in cases of spinal caries, the object here being to remove the laminae against which the medulla spinalis is pressed by the inflammatory mass, and (iii) for the removal of tumours growing inside the vertebral canal and compressing the medulla spinalis. If such cases be taken early, very satisfactory results are obtained.

THE STERNUM.

The sternum (figs. 275 to 277) is an elongated, flattened bone, forming the middle portion of the anterior wall of the thorax. Its average length in the adult is about 17 cm., and is rather greater in the male than in the female. Its upper end supports the clavicles, and its margins articulate with the cartilages of the first seven pairs of ribs. It consists of three parts, named from above downwards, the *manubrium*, the *body*, and the *xiphoid process*; in early life the body consists of four segments or *sternebrae*. In its natural position the inclination of the bone is oblique from above, downwards and forwards. It is slightly convex in front, and concave behind; it is broad above, narrow at the junction of the manubrium with the body, below which it gradually widens as far as a point a little beneath the middle of the body, and then narrows to its lower extremity.

The *manubrium* is of a somewhat triangular form, broad and thick above, narrow below at its junction with the body. Its *anterior surface*, convex from side to side, concave from above downwards, is smooth, and affords attachment on either side to the sternal origins of the Pectoralis major and Sternocleidomastoideus. Its *posterior surface*, concave and smooth, gives origin on either side to the Sternohyoideus and Sternothyroideus. The *superior border* is thick, and presents at its centre the *jugal notch*; on either side of this notch is an oval articular surface, directed upwards, backwards, and lateralwards, for articulation with the sternal end of the clavicle. The *inferior border*, oval and rough, is covered in the recent state with a thin layer of cartilage, for articulation with the upper end of the body. The *lateral borders* are each marked above by a depression for the first costal cartilage, and below by a small articular facet, which, with a similar facet on the upper angle of the body, forms a notch for the reception of the sternal end of the costal cartilage of the second rib. Between the depression for the first costal cartilage and the facet for the second is a narrow, curved edge, which slopes from above downwards and medialwards.

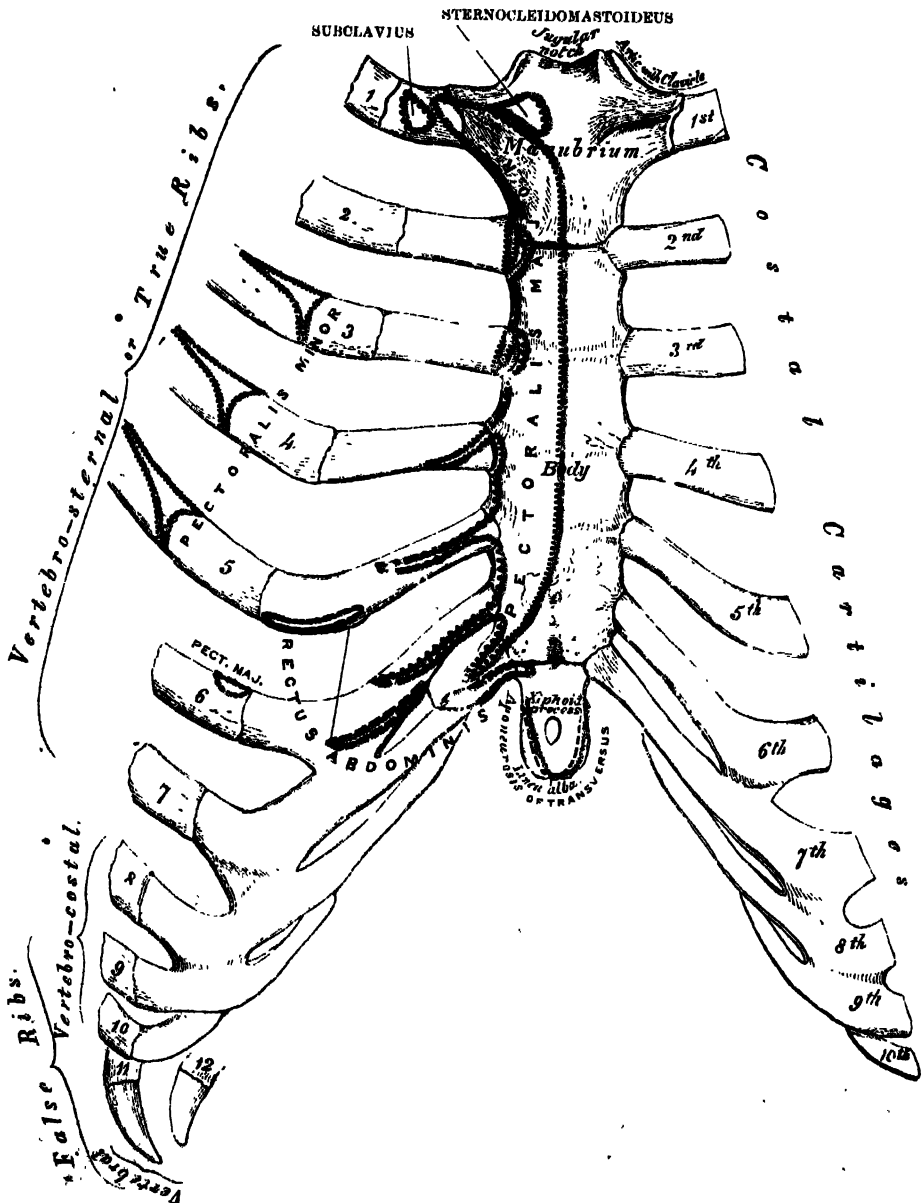
The *body*, longer, narrower, and thinner than the manubrium, attains its greatest breadth close to the lower end. Its *anterior surface* is nearly flat, directed forwards and upwards, and marked by three ridges which cross the bone transversely opposite the third, fourth, and fifth articular depressions.* It affords attachment on either side to the sternal origin of the Pectoralis major. A *sternal foramen*, of varying size and form, is occasionally seen at the junction of the third and fourth pieces of the body. The *posterior surface*, slightly concave, is also marked by three transverse lines, less distinct, however, than those in front; from its lower part, on either side, the *Transversus thoracis* takes origin. The *upper end* is oval and articulates with the manubrium, the junction of the two forming the *sternal angle* (*angulus Ludovici* †). The *lower*

* Paterson (*The Human Sternum*, 1904) found that these ridges were absent in 26.7 per cent.; that a ridge existed opposite the third costal cartilage in 69 per cent.; opposite the fourth in 39 per cent.; and opposite the fifth in 4 per cent.

† Named after the French surgeon Antoine Louis, 1723-1792. The Latin term *angulus Ludovici* is not infrequently mistranslated into English as 'the angle of Ludwig.'

end is narrow, and articulates with the xiphoid process. Each *lateral border* (fig. 277), at its superior angle, has a small facet, which with a similar facet on the manubrium, forms a cavity for the reception of the sternal end of the cartilage of the second rib; below this are four angular depressions which receive the sternal ends of the cartilages of the third, fourth, fifth, and sixth

FIG. 275.—Anterior surface of sternum and costal cartilages.



ribs; the inferior angle has a small facet, which, with a corresponding one on the xiphoid process, forms a notch for the cartilage of the seventh rib. These articular depressions are separated by a series of curved interarticular intervals, which diminish in length from above downwards, and correspond to the intercostal spaces.

It will be observed that most of the cartilages of the true ribs articulate with the sternum at the lines of junction of its primitive component segments; this is well seen in

many of the lower animals, where the parts of the bone remain ununited longer than in man.

The **xiphoid process** is the smallest piece ; it is thin and elongated, cartilaginous in youth, but more or less ossified at its upper part in the adult. Its **anterior surface** affords attachment on either side to the anterior costoxiphoid ligament and a small part of the Rectus abdominis ; its **posterior surface**, to the posterior costoxiphoid ligament and to some of the fibres of the Diaphragm and Transversus thoracis ; its **lateral borders**, to the aponeuroses of the abdominal muscles. Above, it articulates with the lower end of the body of the bone, and on the front of each superior angle is a facet for part of the cartilage of

FIG. 276.—Posterior surface of sternum.

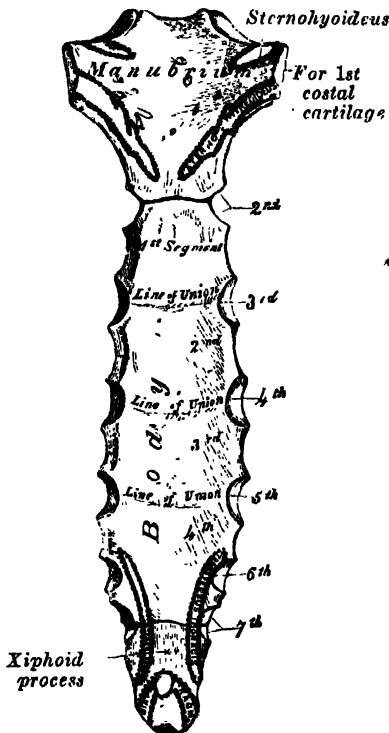
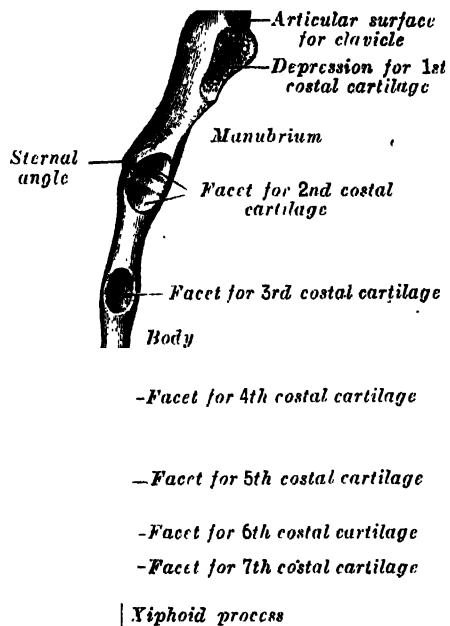


FIG. 277.—Lateral border of sternum.



the seventh rib ; its pointed inferior extremity gives attachment to the linea alba. The xiphoid process varies much in form ; it may be broad and thin, pointed, bifid, perforated, curved, or deflected considerably to one or other side.

Structure.—The sternum is composed of highly vascular spongy substance covered by a layer of compact bone which is thickest on the manubrium between the articular facets for the clavicles.

Ossification.—The sternum originally consists of two cartilaginous *sternal plates*, one on either side of the median plane. Opposite the first seven pairs of ribs these plates fuse with each other in the middle line to form the cartilaginous sternum. The bone is ossified from six centres : one for the manubrium, four for the body, and one for the xiphoid process (fig. 278). These centres appear in the intervals between the articular depressions for the costal cartilages, in the following order : in the manubrium and first piece of the body, during the sixth month of foetal life ; in the second and third pieces of the body, during the seventh month of foetal life ; in its fourth piece, shortly before birth ; and in the xiphoid process, in the third year or much later.* Two small episternal centres sometimes appear, one on either

* Paterson (*op. cit.*) found the fourth or lowest centre for the body present only in 26·9 per cent. of cases.

side of the jugular notch ; they are probably vestiges of the episternal bone of the monotremata and lizards. The manubrium may have two, three, or more centres ; when two are present, they are generally situated one above the other, the upper being the larger. The first segment of the body has seldom more than one centre ; but the second, third, and fourth segments are often ossified from two laterally placed centres, the incomplete union of which explains the occurrence of the foramen or fissure which is occasionally seen in this part of the bone. Union between the centres of the body begins about puberty, and proceeds from below upwards (fig. 279) ; by the age of twenty-five they are all united. The xiphoid process usually fuses with the body about the age of forty years, but may remain ununited in old age.

FIG. 278.—Ossification of the sternum.

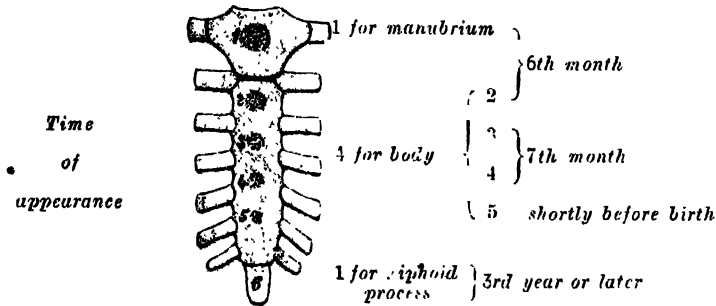
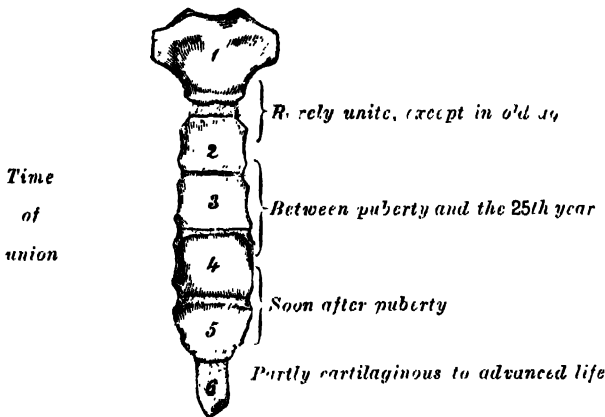


FIG. 279.



In advanced life the manubrium is occasionally joined to the body by bone, but when this takes place the bony substance is generally only superficial, the central portion of the intervening cartilage remaining unossified.

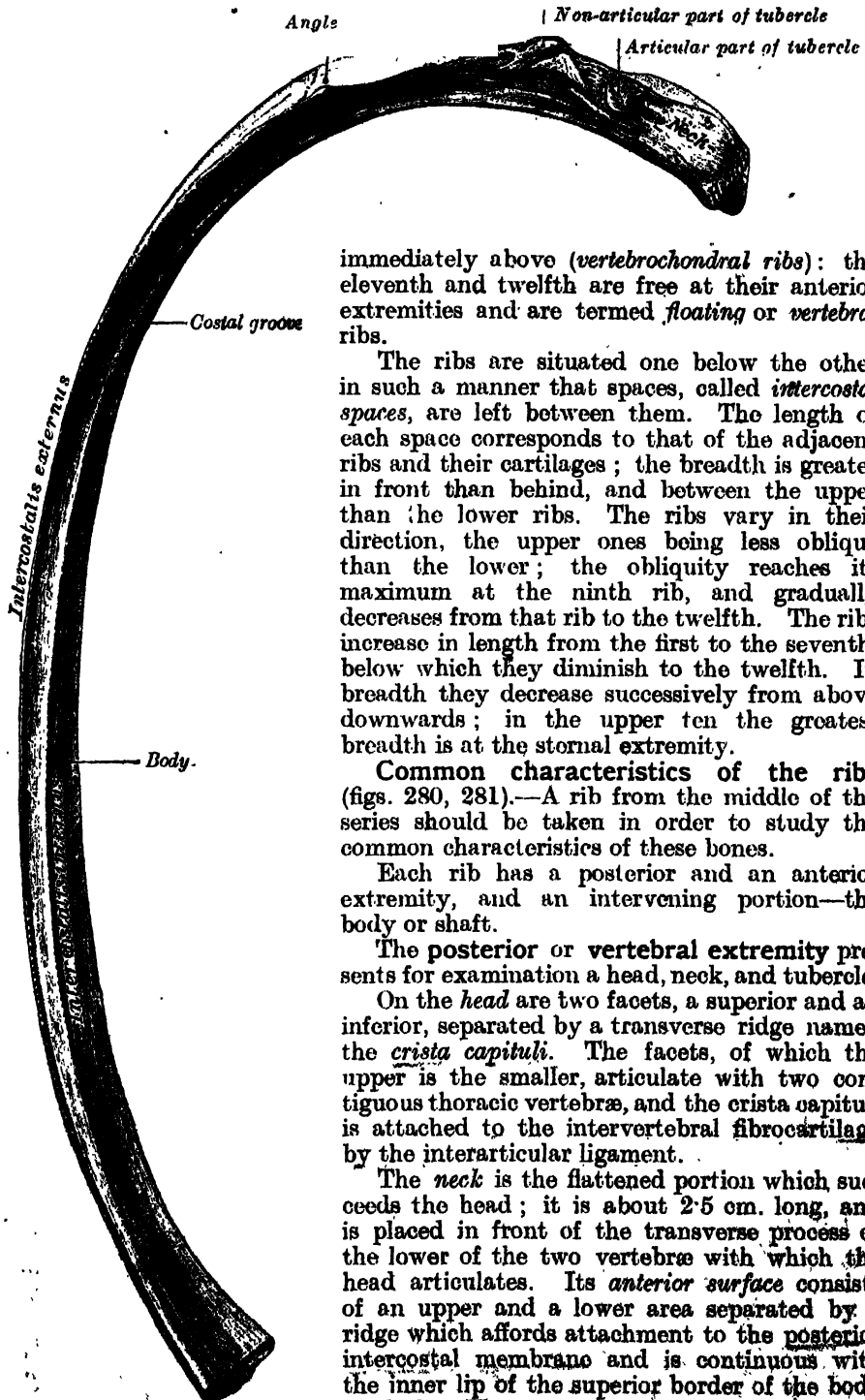
THE RIBS (COSTÆ)

The ribs are elastic arches of bone, which are connected behind with the vertebral column, and form a large part of the skeleton of the thorax. They are twelve in number on either side ; but this number may be increased by the development of a cervical or lumbar rib, or may be reduced to eleven. The first seven are connected in front, through the intervention of the costal cartilages, with the sternum (fig. 275) ; they are called *true ribs* (costæ veræ).*

* Sometimes the eighth rib cartilage articulates with the sternum ; this condition occurs more frequently on the right than on the left side.

The remaining five are *false ribs* (*costæ spuriae*); of these the cartilages of the eighth, ninth and tenth are each joined to the cartilage of the rib

FIG. 290.—A central rib of the left side. Inferior aspect.



immediately above (*vertebrochondral ribs*): the eleventh and twelfth are free at their anterior extremities and are termed *floating* or *vertebral ribs*.

The ribs are situated one below the other in such a manner that spaces, called *intercostal spaces*, are left between them. The length of each space corresponds to that of the adjacent ribs and their cartilages; the breadth is greater in front than behind, and between the upper than the lower ribs. The ribs vary in their direction, the upper ones being less oblique than the lower; the obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth. The ribs increase in length from the first to the seventh, below which they diminish to the twelfth. In breadth they decrease successively from above downwards; in the upper ten the greatest breadth is at the sternal extremity.

Common characteristics of the ribs (figs. 280, 281).—A rib from the middle of the series should be taken in order to study the common characteristics of these bones.

Each rib has a posterior and an anterior extremity, and an intervening portion—the body or shaft.

The **posterior** or **vertebral extremity** presents for examination a head, neck, and tubercle.

On the *head* are two facets, a superior and an inferior, separated by a transverse ridge named the *crista capituli*. The facets, of which the upper is the smaller, articulate with two contiguous thoracic vertebrae, and the *crista capituli* is attached to the intervertebral fibrocartilage by the interarticular ligament.

The *neck* is the flattened portion which succeeds the head; it is about 2.5 cm. long, and is placed in front of the transverse process of the lower of the two vertebrae with which the head articulates. Its *anterior surface* consists of an upper and a lower area separated by a ridge which affords attachment to the posterior intercostal membrane and is continuous with the inner lip of the superior border of the body or shaft. The upper area, of varying size and

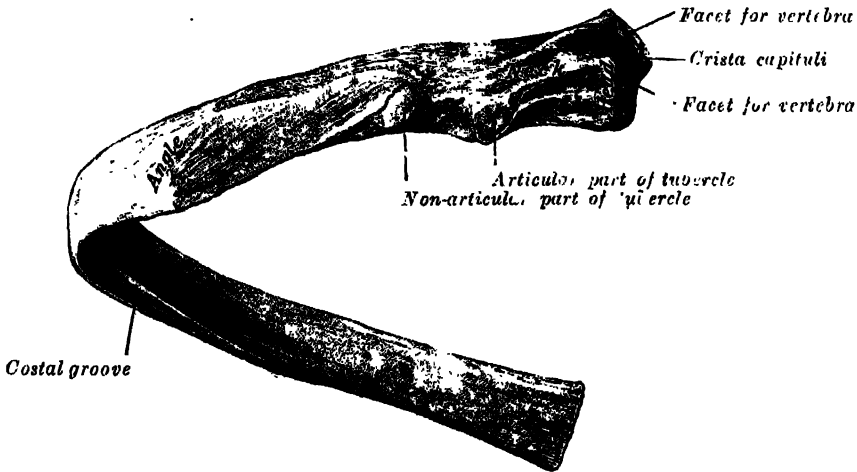
more or less triangular in shape, is separated from the posterior intercostal membrane by some fatty tissue; the lower is smooth and covered by the

costal pleura. Its *posterior surface* is rough for the attachment of the ligament of the neck of the rib, and perforated by numerous foramina. On its *superior border* is a rough crest, the *crista colli costæ*, for the attachment of the anterior costo-transverse ligament; from this crest a line can be followed into the outer lip of the superior border of the body or shaft. Its *inferior border*, more or less rounded, gives attachment to the posterior intercostal membrane and is continuous laterally with the superior border of the costal groove.

On the posterior surface of the rib at the junction of the neck and body, and nearer the lower than the upper border, is the *tubercle*; it is more prominent in the upper than in the lower ribs, and consists of an articular and a non-articular portion. The *articular portion*, the lower and more medial, has a small, oval surface for articulation with the end of the transverse process of the lower of the two vertebræ to which the head is connected. The *non-articular portion* is a rough elevation, and affords attachment to the ligament of the tubercle.

The *body or shaft* is thin and flat, with an external and an internal surface; and a superior and an inferior border. The *external surface* is convex, smooth,

FIG. 281.—A central rib of the left side viewed from behind.



and marked, a little in front of the tubercle, by a prominent line, directed downwards and lateralwards; this gives attachment to a tendon of the *ilio-costalis muscle*, and is called the *angle*. At this point the bone is bent in two directions, and at the same time twisted on its long axis. If the rib be laid upon its lower border, the portion of the body in front of the angle rests upon this border, while the portion behind the angle is bent medialwards and at the same time tilted upwards; as the result of the twisting, the external surface looks downwards behind the angle and slightly upwards in front. The distance between the angle and the tubercle is progressively greater from the second to the tenth ribs. Between the angle and the tubercle the external surface is rounded, rough, and irregular, and serves for the attachment of the *Longissimus dorsi*. Near the sternal end of the external surface is an indistinct oblique line, the *anterior angle*. The *internal surface* is concave, smooth, directed a little upwards behind the angle, a little downwards in front of it, and is marked by a ridge which commences at the lower extremity of the head; this ridge is strongly marked as far as the angle, and is lost at the junction of the anterior and middle thirds of the bone. Between it and the inferior border is the *costal groove*, for the intercostal vessels and nerve; within the groove are seen the orifices of numerous small foramina for nutrient vessels, which traverse the shaft obliquely from before backwards. At the posterior part of the bone, this groove occupies the inferior border, but just in front of the angle, where it is deepest and broadest, it is on the internal surface. The

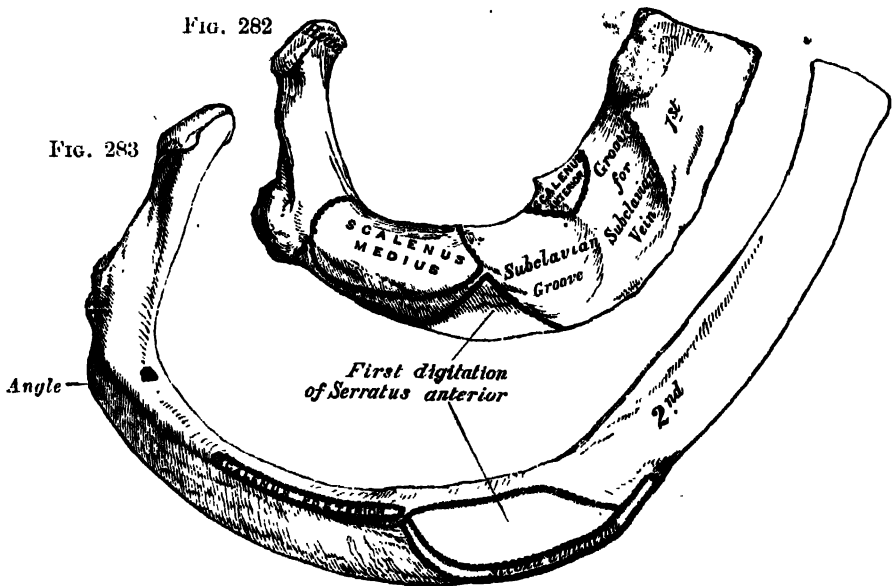
superior edge of the groove is rounded and serves for the attachment of an *Intercostalis internus*; it is continuous behind with the inferior border of the neck. The inferior edge of the costal groove constitutes the *inferior border* of the rib, and gives attachment to an *Intercostalis externus*. The *superior border*, thick and rounded, is marked by an external and an internal lip, more distinct behind than in front; the former gives attachment to an *Intercostalis externus*, the latter to an *Intercostalis internus*.

On the *anterior or sternal extremity* is an oval, cup-shaped depression, into which the lateral end of the costal cartilage is received.

The first, second, tenth, eleventh, and twelfth ribs present certain variations, and require special consideration.

The first rib (fig. 282) is the most curved and usually the shortest of all the ribs; it is broad and flat, its surfaces looking upwards and downwards, and its borders inwards and outwards. The *head* is small, rounded, and has only a single, nearly circular, articular facet, which articulates with the upper

First and second ribs



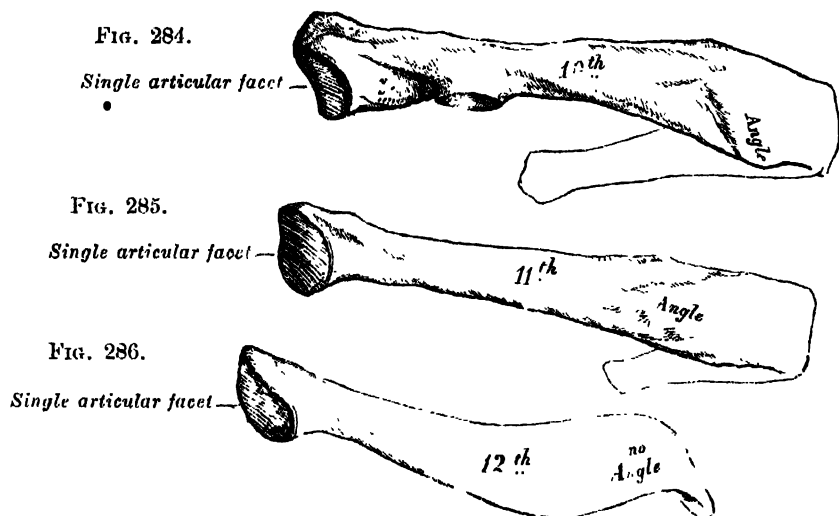
part of the side of the body of the first thoracic vertebra. The *neck* is somewhat rounded. The *tubercle*, thick and prominent, is directed upwards and backwards; on its medial surface is an oval facet for articulation with the transverse process of the first thoracic vertebra. At the tubercle the rib is bent, so that the head of the bone is directed slightly downwards. There is no angle. The *upper surface* of the body is marked by two shallow grooves, separated from each other by a slight ridge prolonged internally into the *scalene tubercle*, for the attachment of the *Scalenus anterior*; the groove in front of the tubercle transmits the subclavian vein, that behind the tubercle the subclavian artery and the lowest trunk of the brachial plexus.* In front of the anterior groove the *Subclavius* muscle takes origin, while behind the posterior groove is a rough area for the attachment of the *Scalenus medius*. The *under surface* is smooth, and destitute of a costal groove. The *outer border* is convex, thick and rounded behind, but thin in front. Immediately behind the subclavian groove it gives origin to the upper part of the first digitation of the *Serratus anterior*; the *inner border* is concave and thin, and marked near its centre by the *scalene tubercle*. The *anterior extremity* is larger and thicker than that of any of the other ribs.

* See article by Wood Jones, *Anat. Anzeiger*, Bd. xxxvi. 1910.

The second rib (fig. 283) is about twice the length of the first, but has a similar curvature. The non-articular portion of the *tubercle* is often small. The *angle* is slight, and situated close to the tubercle. The *body* is not twisted, so that both ends of it touch any plane surface upon which it may be laid; but at the tubercle there is an upward convexity, similar to, but smaller than, that found in the first rib. The *external surface* of the body is convex, and looks upwards and a little outwards; near its middle is a rough eminence for the origin of the lower part of the first and the whole of the second digitation of the *Serratus anterior*; behind and above this the *Scalenus posterior* is inserted. The *internal surface*, smooth and concave, is directed downwards and a little inwards; on its posterior part there is a short costal groove.

The tenth rib (fig. 284) has only a single articular facet on its head.

The eleventh and twelfth ribs (figs. 285 and 286) have each a single articular facet on the head, which is of rather large size; they have no necks or tubercles, and are pointed at their anterior ends. The eleventh has a slight



angle and a shallow costal groove. The twelfth has neither; it is much shorter than the eleventh, and its head is inclined slightly downwards. Sometimes the twelfth rib is shorter than the first.

Structure.—The ribs consist of highly vascular spongy substance enclosed in a thin layer of compact bone.

Ossification.—Each rib, with the exception of the first and the last two, is ossified from four centres; a primary centre for the body, and three secondary centres, one for the head and one each for the articular and non-articular parts of the tubercle.* The first rib has three centres, viz.: a primary one for the body, a secondary centre for the head, and one for the tubercle. The eleventh and twelfth ribs, being destitute of tubercles, have each only two centres. Ossification begins near the angle towards the end of the second month of foetal life, and is seen first in the sixth and seventh ribs. The epiphyses for the head and tubercle make their appearance between the sixteenth and twentieth years, and are united to the body about the twenty-fifth year.

THE COSTAL CARTILAGES

The costal cartilages (fig. 275) are bars of hyaline cartilage which extend forwards from the anterior ends of the ribs and contribute very materially to the elasticity of the walls of the thorax. The first seven pairs are connected

* Fawcett (*Journal of Anatomy and Physiology*, vol. xiv.) states that 'in all probability there is usually no epiphysis on the non-articular part of the tuberosity below the sixth or seventh rib.'

with the sternum; the eighth, ninth, and tenth are each articulated with the lower border of the cartilage immediately above; the last two have pointed extremities which end in the wall of the abdomen. The costal cartilages vary in their length, breadth, and direction. They increase in length from the first to the seventh, then gradually decrease to the twelfth. Their breadth, and the intervals between them, diminish from the first to the last. They are broad at their attachments to the ribs, and taper towards their sternal extremities, excepting the first and second, which are of the same breadth throughout, and the sixth, seventh, and eighth, which are enlarged where their margins are in contact. The first cartilage descends a little, the second is horizontal, the third ascends slightly, while the others are angular, following the course of the ribs for a short distance, and then ascending to the sternum or preceding cartilage.

Each costal cartilage has two surfaces, two borders, and two extremities. The *anterior surface* is convex, and looks forwards and upwards: that of the first gives attachment to the costoclavicular ligament and the Subclavius muscle; those of the first six or seven at their sternal ends, to the Pectoralis major. The others are covered by, and give partial attachment to, some of the flat muscles of the abdomen. The *posterior surface* is concave, and directed backwards and downwards; that of the first gives attachment to the Sternothyroideus, those of the third to the sixth inclusive to the Transversus thoracis, and the six inferior ones to the Transversus abdominis and the Diaphragm. The *superior border* is concave, the *inferior* convex; they afford attachment to the Intercostales interni. The inferior borders of the sixth, seventh, eighth, and ninth cartilages present heel-like projections at the points of greatest convexity; a similar heel-like projection occurs on the lower border of the fifth right cartilage in 72 per cent. and on the fifth left cartilage in 50 per cent. (Fawcett). On these projections are oblong facets which articulate respectively with facets on slight projections from the superior borders of the sixth, seventh, eighth, ninth, and tenth cartilages. The *lateral end* of each cartilage is continuous with the osseous tissue of the rib to which it belongs. The *medial end* of the first is continuous with the sternum: the medial ends of the six succeeding ones are rounded and articulate with shallow concavities on the lateral margins of the sternum. The medial ends of the eighth, ninth, and tenth costal cartilages are pointed, and each is connected with the cartilage immediately above. Those of the eleventh and twelfth are pointed and free. In old age the costal cartilages are prone to undergo superficial ossification.

THE THORAX

The skeleton of the thorax, or chest (fig. 287), is an osseocartilaginous cage, containing and protecting the principal organs of respiration and circulation. It is conical in shape, being narrow above and broad below, flattened from before backwards, and longer behind than in front. It is reniform on horizontal section on account of the forward projection of the vertebral bodies.

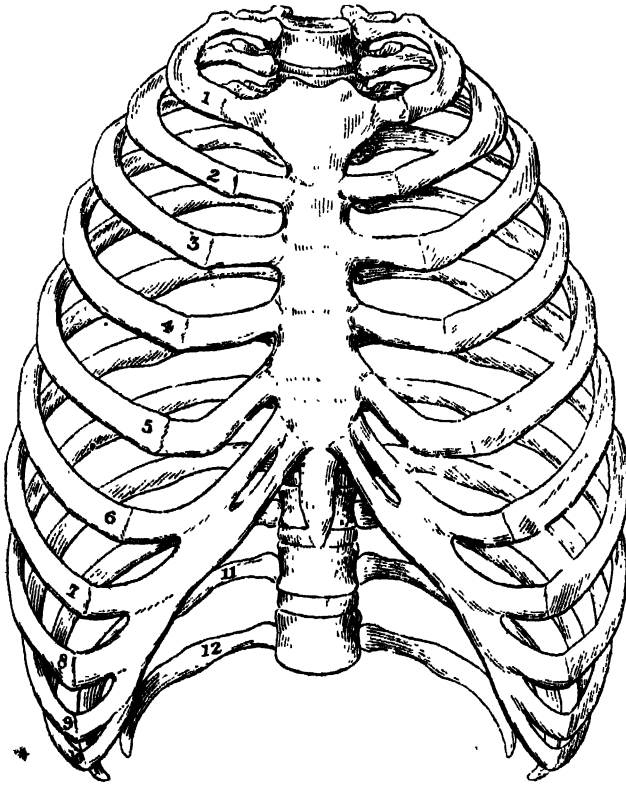
Boundaries.—*Posteriorly* it is formed by the twelve thoracic vertebrae and the posterior parts of the ribs. On either side of the vertebral column is a deep groove in consequence of the lateral and backward direction which the ribs take from their vertebral extremities to their angles. *Anteriorly* it is formed by the sternum and costal cartilages, and this surface is flattened or slightly convex. *Laterally* it is convex, and is formed by the ribs. The ribs and costal cartilages are separated from each other by the intercostal spaces, eleven in number, which are occupied by the Intercostal muscles and membranes.

The *upper opening* of the thorax is reniform in shape; its anteroposterior diameter is about 5 cm., its transverse about 10 cm. It slopes downwards and forwards, and is bounded by the first thoracic vertebra behind, the superior border of the manubrium sterni in front, and the first rib on either side. The *lower opening* is bounded by the twelfth thoracic vertebra behind, by the eleventh and twelfth ribs at the sides, and in front by the cartilages of the

tenth, ninth, eighth, and seventh ribs, which ascend on either side and form an angle, the *subcostal angle*, into the apex of which the xiphoid process projects. The lower opening is wider transversely than from before backwards, and slopes obliquely downwards and backwards; it is closed by the Diaphragm which forms the floor of the thorax.

The thorax of the female differs from that of the male as follows: 1. Its capacity is less. 2. The sternum is shorter. 3. The upper margin of the sternum is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second. 4. The upper ribs are more movable, and so allow a greater expansion of the upper part of the thorax.

FIG. 287.—Front view of the skeleton of the thorax.



Applied Anatomy.—Fracture of the sternum is by no means common, owing, no doubt, to the elasticity of the ribs and their cartilages, which support it like so many springs. The fracture usually occurs in the upper half of the body. Dislocation of the body from the manubrium may take place, and is sometimes described as a fracture.

The bone is frequently the seat of gummatous tumours, and not uncommonly is affected with caries.

The ribs are frequently broken, though from their connexions and shape they are able to withstand great force, yielding under the injury and recovering themselves like a spring. The middle ribs are the most liable to fracture. The first, and to a less extent the second, being protected by the clavicle, are rarely fractured; and the eleventh and twelfth on account of their loose and floating condition enjoy a like immunity. The fracture generally occurs from indirect violence from forcible compression of the chest walls, and the bone then gives way at its weakest part, i.e. just in front of the angle. But the ribs may also be broken by direct violence, in which case the bone is driven inwards at the point struck. Fracture of the ribs is frequently complicated with some injury to the viscera contained within the thorax or upper part of the abdominal cavity; this is most likely to occur in fractures from direct violence.

Fracture of the costal cartilages, or separation of the cartilages from the ribs, may also take place, though they are comparatively rare injuries. In workmen the pressure of tools may displace the xiphoid process inwards.

The ribs are frequently the seat of tuberculous disease, with the formation of a chronic abscess in the chest-wall. This may not immediately overlie the carious portion of rib, as the pus is often directed a considerable distance along the costal groove before appearing beneath the integument.

Resection of a portion of a rib is often required in order to give efficient drainage to an empyema; this is referred to in the description of the respiratory organs.

Cervical ribs derived from the seventh cervical vertebra (page 166) are of not infrequent occurrence, and are important clinically because they may give rise to obscure nervous or vascular symptoms. The cervical rib may be a mere epiphysis articulating only with the transverse process of the vertebra, but more commonly it consists of a defined head, neck and tubercle, with or without a body. It extends lateralwards, or forwards and lateralwards, into the posterior triangle of the neck, where it may terminate in a free end or may join the first thoracic rib, the first costal cartilage, or the sternum.* It varies much in shape, size, direction, and mobility. If it reach far enough forwards, part of the brachial plexus and the subclavian artery and vein cross over it, and are apt to suffer compression in so doing. Pressure on the artery may obstruct the circulation so much that arterial thrombosis results, causing gangrene of the finger-tips. Pressure on the nerves is commoner, and affects the eighth cervical and first thoracic nerves, causing paralysis of the muscles they supply and neuralgic pains and paræsthesia in the area of skin to which they are distributed: no oculosupillary changes are to be found. If these symptoms be severe, removal of the rib or as much of it as causes pressure on the vessels and nerves is called for. The operation is not free from difficulty, and has been followed by paralysis of the muscles and by subclavian aneurysm, due to injuries inflicted in the course of the operation.

The *thorax* is frequently found to be altered in shape in certain diseases.

In *rickets*, the ends of the ribs, where they join the costal cartilages, become enlarged, giving rise to the so-called 'rickety rosary,' which in mild cases is only found on the internal surface of the thorax. Lateral to these enlargements the softened ribs sink in, so as to present a groove passing downwards and lateralwards on either side of the sternum. This bone is forced forwards by the bending of the ribs, and the anteroposterior diameter of the chest is increased. The ribs affected are the second to the eighth, the lower ones being prevented from falling in by the presence of the liver, stomach, and spleen; and when the abdomen is distended, as it often is in rickets, the lower ribs may be pushed outwards, causing a transverse groove (Harrison's sulcus) just above the costal arch. This deformity or forward projection of the sternum, often asymmetrical, is known as 'pigeon-breast,' and may be taken as evidence of active or old rickets except in cases of primary spinal curvature. In many instances it is associated in children with obstruction in the upper air-passages, due to enlarged tonsils or adenoid growths. In some rickety children or adults, and also in others who give no history or further evidence of having had rickets, an opposite condition obtains. The lower part of the sternum and often the xiphoid process as well are deeply depressed backwards, producing an oval hollow in the lower sternal and upper epigastric regions. This is known as 'funnel-breast' (German, *Trichterbrust*); it never appears to produce the least disturbance of any of the vital functions. The *phthisical chest* is often long and narrow, with great obliquity of the ribs and projection of the scapulæ. In *pulmonary emphysema* the chest is enlarged in all its diameters, and presents on section an almost circular outline. It has received the name of the 'barrel-shaped chest.' In severe cases of *lateral curvature of the vertebral column* the thorax becomes much distorted. In consequence of the rotation of the bodies of the vertebrae which takes place in this disease, the ribs opposite the convexity of the dorsal curve become extremely convex behind, being thrown out and bulging, and at the same time flattened in front, so that the two ends of the same rib are almost parallel. Coincidentally with this the ribs on the opposite side, on the concavity of the curve, are sunk and depressed behind, and bulging and convex in front.

It is commonly said that in tuberculosis of the lungs the chest is characteristically 'flat,' that is to say, that the ratio of its anteroposterior to its transverse diameter is less than the normal. But by careful measurement in a large number of cases, Woods Hutchinson has shown that this is not so. Taking the transverse diameter of the chest at the nipple level as =100, he finds that in the normal adult man between the ages of 20 and 44 the anteroposterior diameter =71. In 82 phthisical subjects it was =79·5, and in 30 'flat-chested' persons was =80. He explains the error as an optical illusion, due to rolling forwards of the shoulders in the 'flat-chested'; the back is seen to be correspondingly rounded and protuberant, while the forward position of the shoulders and clavicles lends an appearance of flattening to the chest.

More or less shrinkage of one side of the thorax is often seen as a consequence of adhesive pleurisy, in which the pulmonary and parietal pleura adhere closely to one another and the lung becomes collapsed and fibrosed. If this process be at all complete, great deformity of the chest results, the ribs on the affected side falling in, together with obliteration of the intercostal spaces; the contents of the mediastinal cavity are pulled over towards the affected side, and the other lung becomes emphysematous compensatory. The vertebral column becomes scoliotic, with the concavity of the curve towards the affected side.

* W. Thorburn, *The Med. Chronicle*, Manchester, 4th series, xiv. 1907.

THE SKULL

The skull is supported on the top of the vertebral column, and is of an ovoid shape, wider behind than in front. It is composed of a series of flattened or irregular bones which, with the exception of the mandible, are immovably jointed together. It is divisible into : (1) the *cranium*, which consists of fifteen bones, and (2) the *skeleton of the face*, which consists of seven, as follows :

	(Cranium, 15 bones	Occipital. Sphenoidal. Two Temporals. Two Parietals. Frontal. Ethmoidal. Two Inferior Nasal Conchæ. Two Lacrimals. Two Nasals. Vomer. Two Maxillæ. Two Palatines. Two Zygomatics. Mandible.
Skull, 22 bones		
	Face, 7 bones	

The hyoid bone, situated at the root of the tongue and attached to the base of the skull by ligaments, is described in this section.

CRANIAL BONES (OSSA CRANII)

THE OCCIPITAL BONE (OS OCCIPITALE)

The occipital bone (figs. 288, 289), situated at the posterior and inferior part of the cranium, is trapezoid in shape and concave forwards. It is pierced by a large oval aperture, the *foramen magnum*, through which the cranial cavity communicates with the vertebral canal. The expanded plate above and behind this foramen is named the *squama* ; the thick, somewhat quadrilateral piece in front of it is called the *basilar part* ; whilst on either side of it is the *lateral portion*.

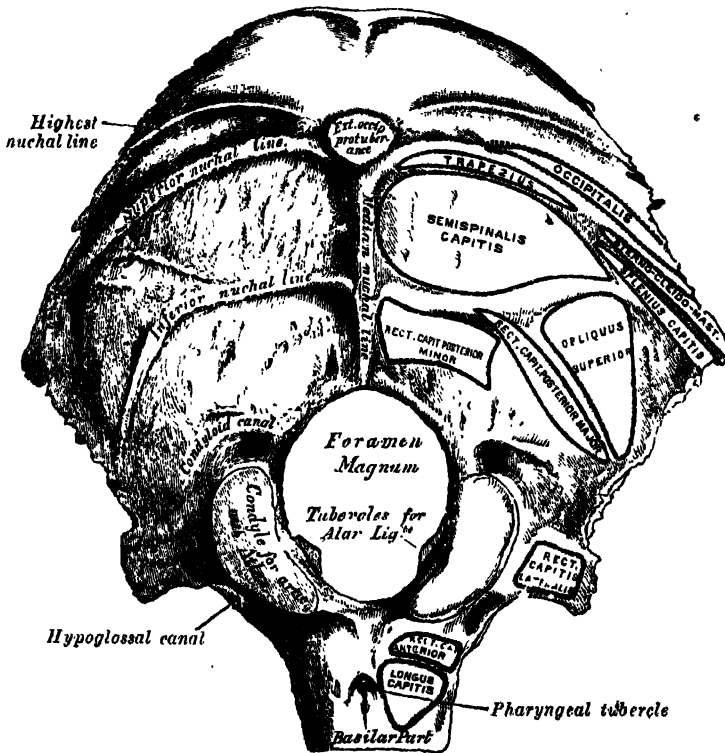
The *squama*, situated above and behind the foramen magnum, is curved from above downwards and from side to side.

The *external surface* is convex and presents midway between the summit of the bone and the foramen magnum a prominence, the *external occipital protuberance*. Extending lateralwards from this on either side are two curved lines, one a little above the other. The upper, often faintly marked, is named the *highest nuchal line* (linea nuchæ suprema), and to it the galea aponeurotica (epicranial aponeurosis) is attached. The lower is termed the *superior nuchal line*. The part of the external surface above the highest nuchal lines is named the *planum occipitale* ; it is smooth, and covered by the Occipitalis muscle ; the part below, termed the *planum nuchale*, is rough and irregular for the attachment of several muscles. From the external occipital protuberance a ridge, the *median nuchal line*, often faintly marked, descends to the foramen magnum, and affords attachment to the ligamentum nuchæ ; running lateralwards from the middle of this line on either side is the *inferior nuchal line*. Several muscles (fig. 288) are attached to the outer surface of the squama, thus : the superior nuchal line gives origin to the Occipitalis and Trapezius, and insertion to the Sternocleidomastoideus and Splenius capitis ; into the surface between the superior and inferior nuchal lines the Semispinalis capitis and the Obliquus capitis superior are inserted ; the inferior nuchal line and the area below it receive the insertions of the Recti capitis posteriores major and minor. The posterior atlanto-occipital membrane is attached around the

posterolateral part of the foramen magnum, just outside the margin of the foramen.

The *internal surface* is deeply concave and divided into four fossæ by a *cruciate eminence*. The upper two fossæ are triangular, and lodge the posterior parts of the occipital lobes of the cerebrum; the lower two are quadrilateral and support the hemispheres of the cerebellum. At the point of intersection of the four divisions of the cruciate eminence is the *internal occipital protuberance*. The upper division of the median part of the cruciate eminence runs from this protuberance to the superior angle of the bone, and on one side of it (generally the right) is a wide groove, the *sagittal sulcus*, which lodges the hinder part of the superior sagittal sinus; to the margins of this sulcus the posterior part of the *falx cerebri* is attached. The lower division of the median part of the

FIG. 288.—Occipital bone. External surface.



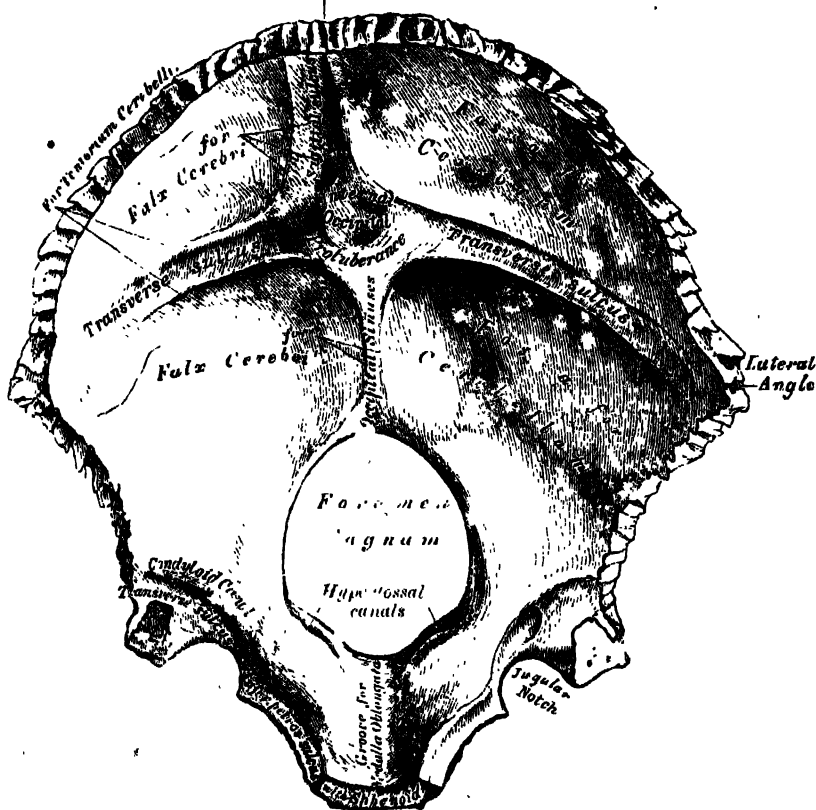
cruciate eminence is prominent, and is named the *internal occipital crest*; it gives attachment to the *falx cerebelli*, and bifurcates near the foramen magnum; in the attached margin of this falx is the *occipital sinus*, which is sometimes duplicated. At the lower part of the internal occipital crest, a small depression is sometimes distinguishable; it is termed the *vernian fossa*, since it is occupied by part of the vermis of the cerebellum. *Transverse sulci*, one on either side, extend lateralwards from the internal occipital protuberance; they accommodate the transverse sinuses, and their margins give attachment to the *tentorium cerebelli*. The right transverse sulcus is usually larger than the left, and continuous with the sagittal sulcus; but the left may be larger than the right, or the two may be almost equal in size. The angle of union of the superior sagittal and transverse sinuses is named the *confluence of the sinuses* or *torcular Herophili*,* and its position is indicated by a depression on one or other side of the protuberance.

*Columns of blood coming in different directions were supposed to be pressed together at this point (*torcular*, a wine-press).

The *superior angle* of the squama articulates with the occipital angles of the parietal bones, and, in the foetal skull, corresponds in position with the *occipital fonticulus* (posterior fontanelle). The *lateral angles* are at the extremities of the transverse sulci; each is received into the interval between the mastoid angle of the parietal and the mastoid part of the temporal. The *lambdoidal* or *superior borders* extend from the superior to the lateral angles; they are serrated for articulation with the occipital borders of the parietal bones, and form by this union the lambdoidal suture. The *mastoid* or *inferior borders* extend from the lateral angles to the jugular processes; each articulates with the mastoid process of the corresponding temporal bone.

FIG. 289.—Occipital bone. Internal surface.

Superior Angle



The lateral parts are situated at the sides of the foramen magnum ; on their *inferior surfaces* are two oval processes named the *occipital condyles* for articulation with the superior facets of the atlas or first cervical vertebra. The condyles are oval or reniform in shape, with their long axes running forwards and medialwards, so that their anterior extremities are closer together than their posterior, and encroach on the basilar portion of the bone ; the posterior extremities extend back to the level of the middle of the foramen magnum. The articular surfaces of the condyles are convex from before backwards and from side to side ; they look downwards and lateralwards, and are occasionally constricted near their centres. On the medial side of each is a rough impression or tubercle for the alar ligament. Above the anterior part of either condyle is the *hypoglossal canal* (anterior condyloid foramen) ; this begins on the cranial surface of the bone a short distance above the anterior part of the foramen magnum, and is directed lateralwards and forwards. It may be partially or completely divided into two by a spicule of bone ; it gives exit to the hypoglossal nerve and entrance to a meningeal branch of the ascending pharyngeal

artery. Behind either condyle is a depression, the *condyloid fossa*, which receives the posterior margin of the corresponding superior facet of the atlas when the head is bent backwards; the floor of this fossa is sometimes perforated by the *condyloid canal*, through which an emissary vein passes from the transverse sinus. Extending lateralwards from the posterior half of the condyle is the *jugular process*, a quadrilateral plate of bone, indented in front by the *jugular notch* which, in the articulated skull, forms the posterior part of the jugular foramen. The jugular notch may be divided into two by a bony spicule, the *intrajugular process*, which projects forwards and lateralwards. The under surface of the jugular process is rough, and gives attachment to the Rectus capitis lateralis muscle; from this surface an eminence, the *paramastoid process*, sometimes projects downwards, and may be of sufficient length to articulate with the transverse process of the atlas. Laterally the jugular process presents a rough quadrilateral or triangular area which is joined to the

jugular surface of the temporal bone by a plate of cartilage; after the age of twenty-five this plate tends to ossify.

On the *upper surface* of the lateral part is an oval eminence, the *tuberculum jugulare*, which overlies the hypoglossal canal; it is crossed by the glossopharyngeal, vagus, and accessory nerves. On the upper surface of the jugular process is a deep groove which curves medialwards and forwards and is continuous with the jugular notch. This groove lodges the terminal part of the transverse sinus, and, close to its medial margin, the condyloid canal opens into it.

The *basilar part* extends forwards and upwards from the foramen magnum and presents *in front* an area more or less quadrilateral in outline. In the young skull this area is rough and uneven, and is joined to the body of the sphenoidal bone by a plate of cartilage. By the twenty-fifth year

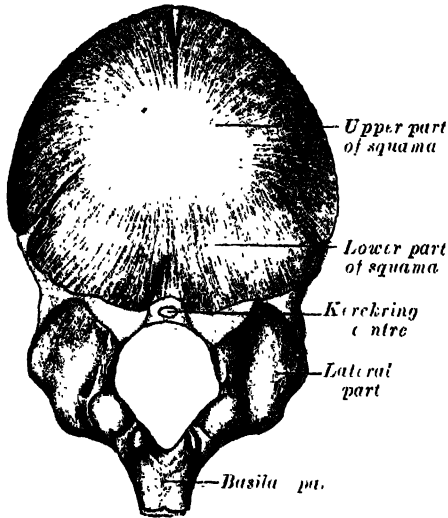


FIG. 290.—Occipital bone at birth.

this plate of cartilage has undergone ossification, and the occipital and sphenoidal bones are fused.

On its *lower surface*, about 1 cm. in front of the foramen magnum, is the *pharyngeal tubercle* which gives attachment to the fibrous raphe of the pharynx. On either side of the middle line the Longus capitis and Rectus capitis anterior are inserted, and immediately in front of the foramen magnum the *anterior atlanto-occipital membrane* is attached.

The *upper surface* consists of a broad, shallow groove which inclines upwards and forwards from the anterior border of the foramen magnum; it supports the medulla oblongata and lower part of the pons, and near the margin of the foramen gives attachment to the membrana tectoria. On the lateral margins of this surface are the *inferior petrosal sulci* for the inferior petrosal sinuses, and below each of these sulci the lateral margin of the basilar part is rough for articulation with the petrous part of the temporal bone.

The *foramen magnum* is a large oval aperture with its long diameter anteroposteriorly; it is wider behind than in front, where it is encroached upon by the occipital condyles. It transmits the medulla oblongata and its membranes, the spinal portions of the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, the membrana tectoria, and the alar ligaments.

Structure.—The occipital, like the other cranial bones, consists of two compact lamellæ, called the *outer and inner tables*, between which is the spongy substance or *diploë*; the bone is especially thick at the ridges, protuberances, condyles, and anterior portion of the basilar part; in the lower parts of the inferior fossæ it is thin, semitransparent, and destitute of diploë.

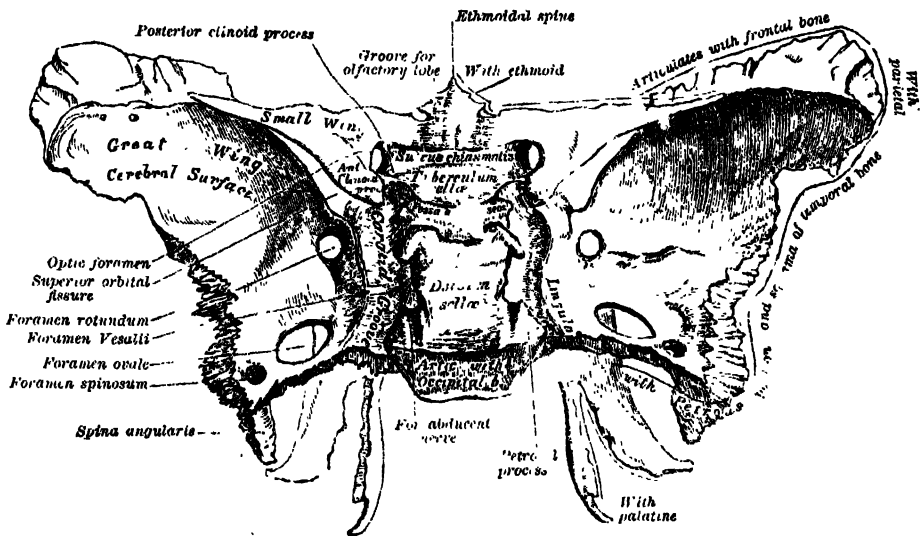
Ossification (fig. 290).—The upper part of the squama, i.e. the part above the

highest nuchal line, is developed in membrane, and is ossified from two centres (Mall),* one appearing on either side of the middle line about the second month of foetal life; it may remain separate throughout life, when it constitutes the *interparietal bone*. The rest of the bone is developed in cartilage. The lower part of the squama is ossified from two centres, which appear about the seventh week of foetal life and soon unite to form a single piece. Union of the upper and lower portions of the squama takes place in the third month of foetal life. An occasional centre appears in the posterior margin of the foramen magnum about the sixteenth week (Kerckring); this forms a separate ossicle (sometimes double) which unites with the rest of the squama before birth. Each of the lateral parts begins to ossify from a single centre during the eighth week of foetal life. The basilar portion is ossified from one centre (Mall), which appears about the sixth week of foetal life. About the fourth year the squama and the two lateral portions unite, and about the sixth year the bone consists of a single piece. Between the eighteenth and twenty-fifth years the occipital and sphenoidal bones unite to form a single bone.

THE SPHENOIDAL BONE (OS SPHENOIDALE)

The **sphenoidal bone** (figs. 291 to 293) is situated at the base of the skull in front of the temporals and the basilar part of the occipital. It somewhat resembles a bat with its wings extended, and consists of a central portion or

FIG. 291.—Sphenoidal bone. Superior surface.



body, two great and two small wings extending lateralwards from the sides of the body, and two pterygoid processes which are directed downwards from the adjoining parts of the body and great wings.

The **body**, more or less cubical in shape, contains two large cavities, the *sphenoidal air-sinuses*, separated from each other by a septum.

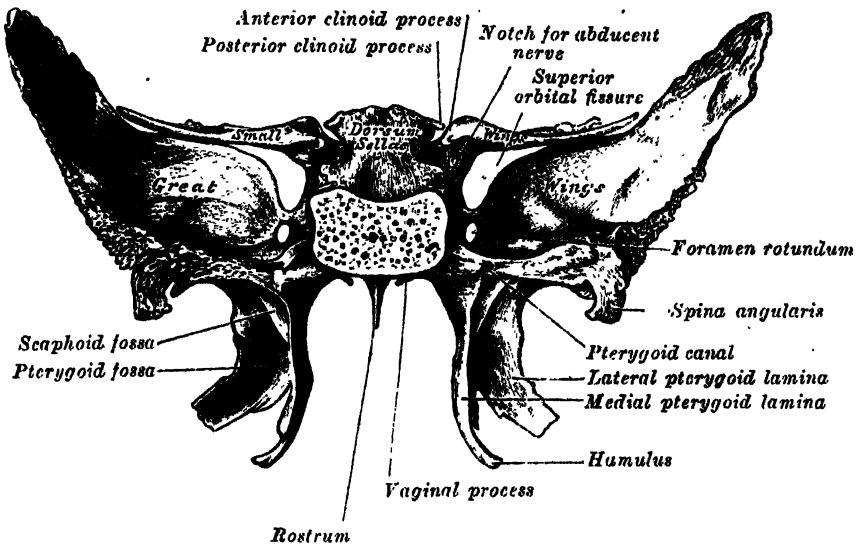
The **cerebral or superior surface** of the body (fig. 291) presents in front the *ethmoidal spine*, for articulation with the lamina cribrosa of the ethmoidal bone: behind this is a smooth surface faintly grooved on either side of the middle line, for the olfactory tracts of the brain. This surface is bounded behind by a ridge, which forms the anterior border of a transverse groove, the *sulcus chiasmatis* (optic groove); this sulcus ends on either side in the *optic foramen*. Posterior to the sulcus is a more or less oval elevation, the *tuberculum sellae*; and behind this is a deep depression, the *sella turcica*, the deepest part of which lodges the hypophysis cerebri and is known as the *fossa hypophyseos*. The anterior boundary of the *sella turcica* is completed laterally by two small eminences, called the *middle clinoid processes*, whilst the posterior boundary

* *American Journal of Anatomy*, vol. v. 1906.

is formed by a square-shaped plate of bone, the *dorsum sellæ*, the superior angles of which end in two tubercles, the *posterior clinoid processes*; these processes vary considerably in form and size, and give attachment to the lateral borders of the tentorium cerebelli. On either side of the dorsum sellæ is a notch for the passage of the abducent nerve, and below this notch a sharp process, the *petrosal process*, which articulates with the apex of the petrous portion of the temporal bone. Behind the dorsum sellæ is a shallow depression, which slopes obliquely backwards, and is continuous with the upper surface of the basilar portion of the occipital bone; it supports the upper part of the pons.

The lateral surfaces of the body are united with the great wings and with the medial pterygoid laminae. Above the attachment of each wing is a broad groove, the *carotid sulcus*, curved somewhat like the italic letter *f*; it lodges

FIG. 292.—Sphenoidal bone. Superior and posterior surfaces.



the internal carotid artery and the cavernous sinus. The carotid sulcus is deepest at the posterior part of the body where it is overhung by the petrosal process, and limited anterolaterally by a sharp margin which is called the *lingula*; the latter overlies the posterior opening of the pterygoid canal.

The posterior surface, quadrilateral in form (fig. 292), is joined, during infancy and adolescence, to the basilar part of the occipital bone by a plate of cartilage which becomes ossified between the eighteenth and twenty-fifth years.

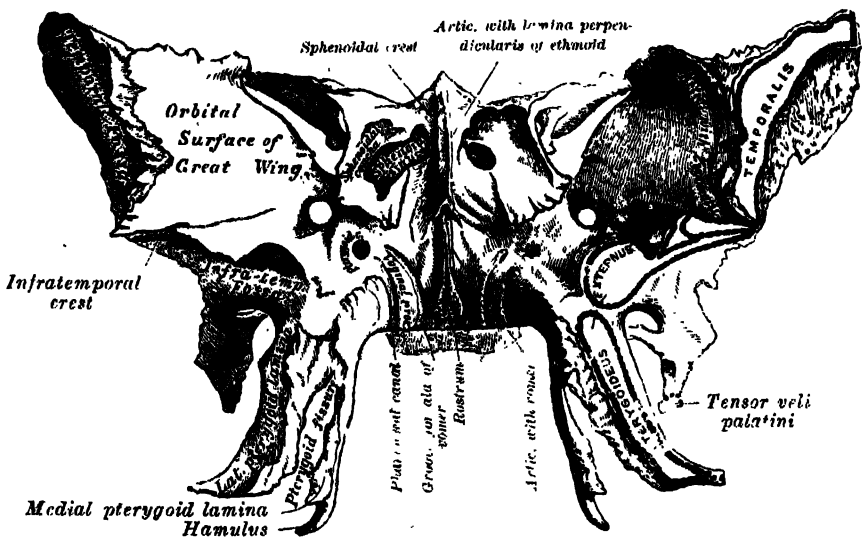
The anterior surface of the body (fig. 293) presents, in the middle line, a triangular crest, the *sphenoidal crest*, which forms a small part of the septum of the nose; its anterior border articulates with the lamina perpendicularis of the ethmoidal bone; its lower, with the vomer. On either side of the crest is an opening leading into the corresponding *sphenoidal air sinus*.* These sinuses are two large, irregular cavities in the body of the bone, separated from one another by a bony septum, which is commonly bent to one or the other side. They vary considerably in form and size,† are seldom symmetrical, and

* Some confusion is occasioned to students commencing the study of anatomy by the name 'sinus' having been given to two different kinds of spaces connected with the skull. It may be as well, therefore, to state here that the 'sinuses' in the interior of the cranium which produce the grooves on the inner surfaces of the bones are venous channels which convey the blood from the brain, while the 'sinuses' external to the cranial cavity (the frontal, sphenoidal, ethmoidal, and maxillary) are hollow spaces in the bones themselves; they communicate with the nasal cavities, and contain air.

† Logan Turner (*The Accessory Sinuses of the Nose*, 1901) gives the following measurements for a sinus of average size: height, 2 cm.; breadth, 1.8 cm.; anteroposterior depth, 2.1 cm. Onodi (*The Accessory Sinuses of the Nose in Children*, 1911) states that in the new-born infant their height is 4 mm. and their width 2 mm., and that at the eighth year their height is from 8 to 12 mm. and their width 11 mm.

are often partially subdivided by bony laminae. A lateral recess may extend from one or other sinus into the great wing and lingula,* while occasionally they reach into the basilar part of the occipital bone nearly as far as the foramen magnum. In the articulated skull they are closed, in front and below, by the *sphenoidal conchæ* (see p. 201), only a round opening being left in the anterior wall of each sinus by which it communicates with the upper and posterior part of the nasal cavity and occasionally with the posterior ethmoidal air-cells. Each half of the anterior surface consists of two parts: (a) an upper and lateral depressed area which completes, with the labyrinth of the ethmoidal bone, the posterior ethmoidal cells; its lateral margin articulates with the lamina papyracea of the ethmoidal bone above, and with the orbital process of the palatine bone below; (b) a lower and medial, triangular, area which is smooth and forms the posterior part of the roof of the nose; near its superior angle is the round orifice of the sphenoidal sinus.

FIG. 293.—Sphenoidal bone. Anterior and inferior surfaces.



The *inferior surface* (fig. 293) presents, in the middle line, a triangular spine, the *sphenoidal rostrum*, which, in the articulated skull, projects into a deep fissure between the anterior parts of the alæ of the vomer. The posterior, triangular parts of the sphenoidal conchæ extend backwards on the sides of the rostrum, and articulate with the alæ of the vomer. On either side of the posterior part of the rostrum, and immediately behind the apex of the sphenoidal concha, is a projecting lamina, the *vaginal process*, directed medialwards from the base of the medial pterygoid lamina, with which it will be described.

The *great wings* (alæ magnæ) are two strong processes of bone, which curve upwards and lateralwards from the sides of the body. The posterior part of each is triangular and fits into the angle between the squama and the petrous portion of the temporal bone; projecting downwards from the apex of this triangular portion is a pointed process named the *spina angularis*, on the medial side of which there is usually a groove, directed downwards and forwards, for the chorda tympani nerve.† To the spina angularis are attached the sphenomandibular ligament and a part of the Tensor veli palatini.

* V. Z. Cope (*Journal of Anatomy and Physiology*, vol. li. part ii.) found a well-marked lateral recess in 72 out of 292 sinuses examined, and has pointed out that the hypophysis, the anterior part of the internal carotid artery, the optic and maxillary nerves, and the nerve of the pterygoid canal may give rise to elevations in the walls of the sinuses.

† B. Clements Lucas, *Proceedings of the Anatomical Society of Great Britain and Ireland*, November, 1894.

The *cerebral* or *superior surface* of the great wing (fig. 291) forms part of the floor of the middle fossa of the skull; it is deeply concave, and presents depressions corresponding with the convolutions of the anterior part of the temporal lobe of the brain. At its antero-medial part is a circular aperture, the *foramen rotundum*, for the passage of the *maxillary nerve*. Behind and lateral to this foramen is the *foramen ovale*, for the transmission of the *mandibular nerve*, the *accessory meningeal artery*, and sometimes the lesser *superficial petrosal nerve*.^{*} Medial to the foramen ovale, a small aperture, the *foramen Vesalii*, is sometimes seen; when present it opens below at the lateral side of the scaphoid fossa, and transmits a small vein from the cavernous sinus. In the posterior angle, near to but in front of the spina angularis, is a short canal, the *foramen spinosum*, which transmits the *nervus spinosus* and the middle meningeal artery.

The *lateral surface* (fig. 293) is convex, and divided by a transverse ridge, the *infratemporal crest*, into an upper or temporal and a lower or infratemporal surface. The *temporal surface*, concave from before backwards, forms a part of the temporal fossa, and gives origin to the Temporalis. The *infratemporal surface* is concave and directed downwards; it forms a part of the infratemporal fossa, and, together with the infratemporal crest, gives origin to the Pterygoideus externus. It is pierced by the foramen ovale and foramen spinosum, and at its posterior part is the spina angularis. Medial to the anterior extremity of the infratemporal crest is a triangular process which serves to increase the attachment of the Pterygoideus externus; a ridge extends downwards and medialwards from this process on to the front of the lateral pterygoid lamina; it forms the anterior limit of the infratemporal surface, and, in the articulated skull, the posterior boundary of the pterygomaxillary fissure.

The *orbital surface* of the great wing (fig. 293), quadrilateral in shape, is directed forwards and medialwards and forms the posterior part of the lateral wall of the orbit. Its upper serrated edge articulates with the orbital plate of the frontal bone; its lateral serrated margin with the zygomatic bone. Its inferior smooth border forms the posterolateral boundary of the inferior orbital fissure. Its medial sharp margin forms the lower boundary of the superior orbital fissure; projecting from near the centre of this margin is a little tubercle which gives attachment to the inferior head of the Rectus lateralis oculi; at the upper end of the margin is a notch for the transmission of the recurrent meningeal branch of the lacrimal artery. Below the medial end of the superior orbital fissure is a grooved surface, which forms the posterior wall of the pterygopalatine fossa, and is pierced by the foramen rotundum.

Margin of great wing (fig. 291).—The portion which extends from the body to the spina angularis is irregular. Its medial half forms the anterior boundary of the *foramen lacerum*, and presents the posterior aperture of the pterygoid canal for the passage of the corresponding nerve and artery. Its lateral half articulates, by means of a synchondrosis, with the petrous portion of the temporal bone, and between the two bones, on the under surface of the skull, is a furrow, the *sulcus tubæ*, for the lodgment of the cartilaginous part of the auditory tube. Extending forwards from the spina angularis is the *squamosal margin*, a concave, serrated edge, bevelled at the expense of the inner surface below, and of the outer surface above, for articulation with the temporal squama. The tip of the great wing, or *parietal angle*, is bevelled at the expense of the inner surface, for articulation with the sphenoidal angle of the parietal bone. Medial to this is a triangular rough area, for articulation with the frontal bone; the medial angle of this area is continuous with the sharp edge which forms the lower boundary of the superior orbital fissure, and the anterior angle with the serrated margin for articulation with the zygomatic bone.

The small wings (*alæ parvæ*) are two triangular plates, which project laterally from the upper and anterior parts of the body, and end in sharp points (fig. 291). The *cerebral surface* of each is smooth, and supports part of the frontal lobe of the brain. The *inferior surface* forms the posterior part of the roof of the orbit, and the upper boundary of the *superior orbital fissure*; its posterior part overhangs the anterior part of the middle fossa of the skull. The *superior orbital fissure* is triangular in shape, and leads from the cavity

^{*} The lesser superficial petrosal nerve sometimes passes through a special canal (*canaliculus innominatus* of Arnold) situated medially to the foramen spinosum.

of the cranium into that of the orbit ; it is bounded medially by the body of the sphenoid ; above, by the small wing ; below, by the medial margin of the orbital surface of the great wing ; and is completed laterally, between the greater and lesser wings, by the frontal bone. It transmits to the orbital cavity the oculomotor, trochlear, and abducent nerves, the three branches of the ophthalmic division of the trigeminal nerve, some filaments from the cavernous plexus of the sympathetic, and the orbital branch of the middle meningeal artery ; and from the orbital cavity the recurrent branch from the lacrimal artery to the dura mater, and the ophthalmic veins. The *frontal or anterior border* is serrated for articulation with the posterior edge of the orbital plate of the frontal bone. The *posterior border* is smooth and is received into the lateral cerebral fissure ; the medial end of this border forms the *anterior clinoid process*, which gives attachment to the free border of the tentorium cerebelli. The anterior and middle clinoid processes are sometimes united by a spicule of bone, and when this occurs the end of the groove for the internal carotid artery is converted into a foramen (*caroticoclinoid*). The small wing is connected to the body by two roots, the upper thin and flat, the lower thick and triangular ; between these is the *optic foramen*, for the transmission of the optic nerve and ophthalmic artery to the orbital cavity.

The *pterygoid processes* (figs. 292, 293), one on either side, descend perpendicularly from the region where the body and great wings unite. Each process consists of a medial and a lateral lamina, the upper parts of which are fused anteriorly ; a vertical groove, the *pterygopalatine sulcus*, descends on the front of the line of fusion, and forms, in the articulated skull, the posterior wall of the pterygopalatine canal. The laminae are separated below by an angular cleft, the *pterygoid fissure*, the rough margins of which articulate with the pyramidal process of the palatine bone. The two laminae diverge behind and enclose between them the V-shaped *pterygoid fossa*, which contains the Pterygoideus internus and Tensor veli palatini. Above this fossa is a small, oval, shallow depression, the *sphenoidal fossa*, which gives origin to part of the Tensor veli palatini. The anterior surface of the pterygoid process is broad and triangular near its root, where it forms the posterior wall of the pterygopalatine fossa and presents the anterior orifice of the *pterygoid canal*.

The *lateral lamina* of the pterygoid process is broad, thin, and everted ; its *lateral surface* forms part of the medial wall of the intratemporal fossa, and gives origin to the lower head of the Pterygoideus externus ; its *medial surface* forms the lateral wall of the pterygoid fossa, and gives origin to the Pterygoideus internus.

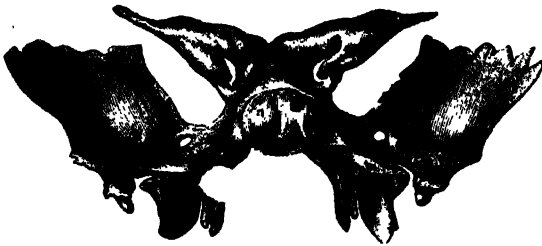
The *medial lamina* of the pterygoid process is narrower and longer than the lateral ; it projects backwards, but curves lateralwards at its lower extremity into a hook-like process, the *pterygoid hamulus*, around which the tendon of the Tensor veli palatini glides. The *lateral surface* of this plate forms part of the pterygoid fossa, and the Tensor veli palatini lies against it ; the *medial surface* constitutes the lateral boundary of the choana or posterior aperture of the corresponding nasal cavity. Superiorly the medial lamina is prolonged on to the under surface of the body as a thin plate, named the *vaginal process*, which articulates anteriorly with the sphenoidal process of the palatine bone and medially with the ala of the vomer. On the under surface of the vaginal process is a *furrow*, which is converted into a canal by the sphenoidal process of the palatine bone, for the transmission of the pharyngeal branch of the internal maxillary artery and the pharyngeal nerve from the sphenopalatine ganglion. The *pharyngobasilar fascia* (pharyngeal aponeurosis) is attached to the entire length of the posterior edge of the medial lamina, and the Constrictor pharyngis superior takes origin from its lower third. At the upper end of the medial pterygoid lamina is a small pyramidal process named the *pterygoid tubercle*, and immediately above this tubercle is the posterior opening of the pterygoid canal. Projecting backwards from near the middle of the posterior edge of this lamina is an angular process, the *processus tubarius*, which supports the *pharyngeal end* of the auditory tube. The anterior margin of the lamina articulates with the posterior border of the vertical part of the palatine bone.

The *sphenoidal conchae* are two thin, curved plates, situated at the anterior and lower parts of the body of the sphenoidal bone ; the upper, *concave surface*

of each forms the anterior wall and the greater part of the floor of the corresponding sphenoidal sinus. They are usually more or less destroyed in the process of disarticulating the skull, but when seen *in situ*, each consists of an anterior, vertical, quadrilateral part and a posterior, horizontal, triangular part. The anterior, vertical portion consists of, (a) an upper and lateral, depressed area which completes the posterior ethmoidal cells and articulates below with the orbital process of the palatine bone; and (b) a medial and lower area, smooth and triangular, which forms part of the roof of the nasal cavity, and is perforated near its superior angle by a round opening through which the sphenoidal sinus communicates with the sphenoidal recess of the nasal cavity. The anterior, vertical portions of the two bones meet in the middle line, and are there continued backwards as the sphenoidal crest. The horizontal triangular portion of the concha forms a part of the roof of the nasal cavity, and completes the sphenopalatine foramen; its medial margin articulates with the rostrum of the sphenoidal bone, and with the ala of the vomer; the apex, directed backwards, lies medial to and above the vaginal process of the medial pterygoid lamina, and articulates with the posterior part of the ala of the vomer. A small portion of the sphenoidal concha sometimes appears in the medial wall of the orbit, between the lamina papyracea of the ethmoidal bone in front, the orbital plate of the palatine bone below, and the frontal bone above.

Ossification.—Until the seventh or eighth month of foetal life the body of the sphenoidal bone consists of two parts—viz. one in front of the tuberculum sellæ, the *presphenoidal part*, with which the small wings are continuous; the other comprising the sella turcica and dorsum sellæ, the *postsphenoidal part*, with which are associated the great wings, and pterygoid processes.

FIG. 294.—Sphenoidal bone at birth. Posterior aspect.



The greater part of the bone is ossified in cartilage. There are fourteen centres in all, six for the presphenoidal and eight for the postsphenoidal part.

Presphenoidal part. About the ninth week of foetal life an ossific centre appears for each of the small wings, just lateral to the optic foramen; shortly afterwards two nuclei appear in the presphenoidal part of the body. The sphenoidal conchæ are each de-

veloped from a centre which makes its appearance about the fifth month*; at birth they consist of small triangular laminae; about the third year they become hollowed out and cone-shaped; about the fourth year they fuse with the labyrinths of the ethmoidal bone, and between the ninth and twelfth years with the sphenoidal bone.

Postsphenoidal part.—The first ossific centres are those for the great wings. One appears below the foramen rotundum in the cartilage which forms the base of each wing about the eighth week; the orbital plate and that part of the sphenoidal bone which is found in the temporal fossa, as well as the lateral pterygoid lamina, are ossified in membrane.† About the fourth month, two centres appear in the postsphenoidal part of the body, one on either side of the sella turcica, and fuse about the middle of foetal life. Each medial pterygoid lamina (with the exception of its hamulus) is ossified in membrane, and its centre probably appears about the ninth or tenth week; the hamulus is chondrified during the third month, and almost at once begins to ossify (Fawcett‡). The medial and lateral pterygoid laminae join about the sixth month. About the fourth month a centre appears for each lingula and speedily joins the rest of the bone.

The presphenoidal and the postsphenoidal parts fuse about the eighth month of foetal life, and at birth the bone is in three pieces (fig. 294): a central, consisting

* According to Cleland, each sphenoidal concha is ossified from four centres.

† Fawcett, *Journal of Anatomy and Physiology*, vol. xlv, 1910.

‡ *Anatomischer Anzeiger*, March 1906.

of the body and small wings, and two lateral, each comprising a great wing and pterygoid process. In the first year after birth the great wings and body unite, and the small wings extend medialwards above the anterior part of the body, and meet to form an elevated smooth surface, termed the *jugum sphenoidale*. By the twenty-fifth year the sphenoidal and occipital bones are completely fused. In the anterior part of the fossa hypophyseos there are occasionally seen the remains of the *canalis craniopharyngeus*, through which, in early foetal life, the hypophysial diverticulum of the buccal ectoderm is transmitted (see page 132).

Traces of the sphenoidal sinuses are seen as early as the third month of foetal life, but the sinuses do not attain their full size until after puberty.

Certain parts of the sphenoidal bone are connected by ligaments which occasionally ossify. The more important of these ligaments are: the *pterygospinous*, stretching between the spina angularis and the upper part of the lateral pterygoid lamina (see *fascia colli*); the *interclinoid*, joining the anterior to the posterior clinoid process; and the *caroticoclinoid*, connecting the anterior to the middle clinoid process.

Applied Anatomy.—Premature ossification or synostosis of the intersphenoidal suture (which normally begins to join at birth) and of the sphenobasilar suture produces a characteristic physiognomy. This is best seen in profile, and consists in an abnormal depression of the bridge of the nose; it is a feature often observed in dwarfs.

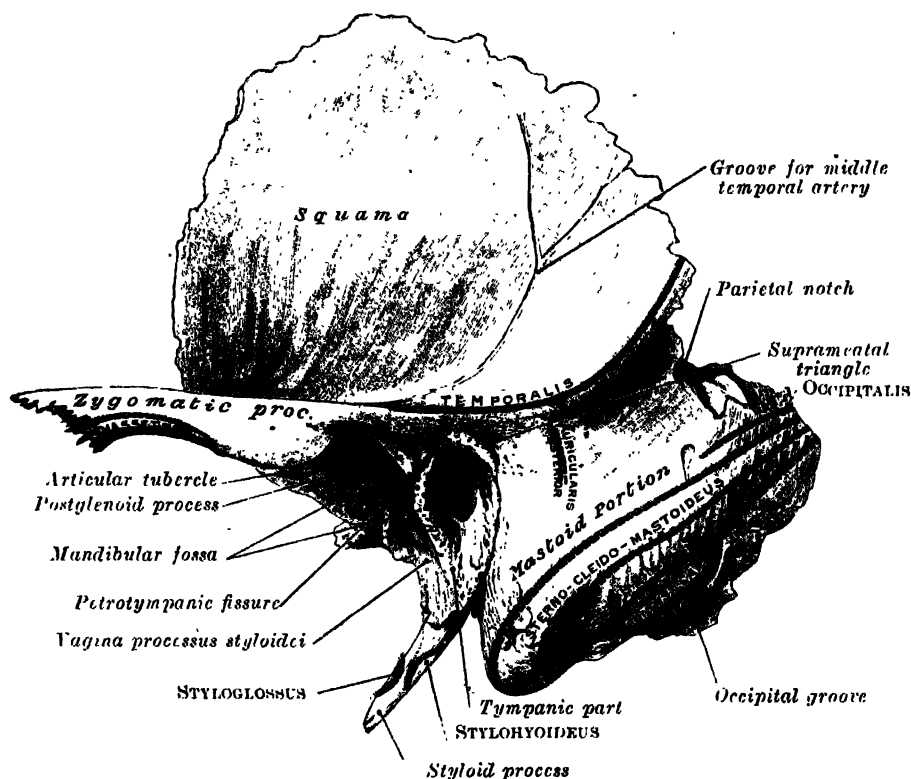
THE TEMPORAL BONE. (OSSA TEMPORALIA)

The **temporal bones** are situated at the sides and base of the skull. Each consists of five parts, viz. the *squama*, the *petrous*, *mastoid*, and *tymppanic parts*, and the *styloid process*.

The **squama** forms the anterior and upper part of the bone, and is scale-like, thin and translucent. Its *temporal or external surface* (fig. 295) is smooth and slightly convex; it forms part of the temporal fossa and gives origin to the Temporalis muscle; on its hinder part, above the opening of the external acoustic meatus, is a vertical groove for the middle temporal artery. A curved line, the *temporal line* or *supramastoid crest*, runs backwards and upwards, across its posterior part; it serves for the attachment of the temporal fascia, and limits the origin of the Temporalis muscle. The boundary between the squama and the mastoid portion of the bone lies about a centimetre below this line, and is frequently indicated by traces of the original mastoid suture. Projecting from the lower part of the squama is a long, arched process, the *zygomatic process*. This process is attached by a broad base and is at first directed laterally, its surfaces looking upwards and downwards; it then twists inwards and runs forwards, its surfaces now looking medially and laterally. The superior border, long and thin, gives attachment to the temporal fascia; the inferior, short and arched, gives origin to some fibres of the Masseter. The lateral surface is convex and subcutaneous; the medial is concave, and gives origin to part of the Masseter. The anterior end is deeply serrated and cut obliquely at the expense of the lower border; it articulates with the zygomatic bone. The posterior end is connected to the squama by two roots—*anterior* and *posterior*. The posterior root, a prolongation of the upper border, runs backwards above the opening of the external acoustic meatus, and is continuous with the temporal line. Between the opening of the external acoustic meatus and the posterior root of the zygomatic process is the *supramental triangle* of Macewen, through which an instrument may be pushed into the tympanic antrum. The anterior root, continuous with the lower border, is short but broad and strong; it is directed medially and ends in an eminence, the *articular tubercle* (*eminentia articularis*). This tubercle is convex from before backwards, and forms the anterior boundary of the mandibular fossa. In front of it is a small triangular area which forms part of the infratemporal fossa, and is separated from the outer surface of the squama by a ridge which is continuous behind with the anterior root of the zygomatic process, and in front, in the articulated skull, with the infratemporal crest on the great wing of the sphenoidal bone. At the junction of the anterior root with the zygomatic process is a tubercle for the attachment of the temporomandibular ligament, and behind the anterior root is an oval depression, forming part of the mandibular fossa. The *mandibular fossa* (glenoid fossa) is bounded, in front, by

the articular tubercle ; it consists of an anterior, articular portion, formed by the squama, and a posterior non-articular portion, formed by the tympanic part of the bone. The articular portion, smooth, oval and deeply concave, articulates with the articular disc of the temporomandibular joint ; the non-articular portion sometimes lodges a small part of the parotid gland. A small, somewhat conical, eminence (postglenoid tubercle) separates the lateral half of the articular portion from the anterior margin of the tympanic part, and is the representative of a prominent tubercle which, in some mammals, descends behind the condyle of the mandible, and prevents its backward displacement. The medial half of the articular portion of the mandibular fossa is separated from the tympanic part of the bone by the lower edge of a plate which projects

FIG. 295.—Left temporal bone. External surface.



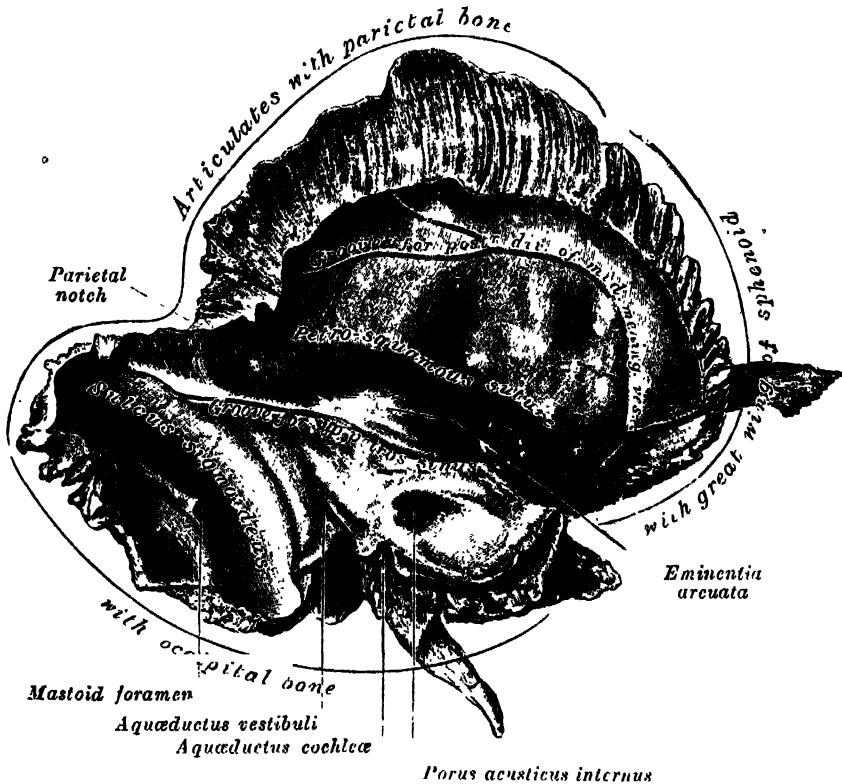
downwards from the tegmen tympani of the petrous part ; the fissure between this plate and the tympanic part is named the *petrotympanic fissure* (Glaserian fissure). The petrotympanic fissure leads into the middle ear or tympanic cavity ; it lodges the anterior process of the malleus, and transmits the anterior tympanic branch of the internal maxillary artery. The medial part of the fissure is known as the *canal of Huguier* ; it transmits the chorda tympani nerve.

The *cerebral* or *internal surface* of the squama (fig. 296) is concave ; it presents depressions corresponding to the convolutions of the temporal lobe of the brain, and grooves for the branches of the middle meningeal vessels ; its lower border is united to the anterior surface of the petrous portion by the *petrosquamous suture*, traces of which are frequently seen.

The *parietal* or *superior border* is thin, and bevelled at the expense of the internal surface ; it overlaps the squamous border of the parietal bone, forming with it the squamosal suture. Posteriorly, the superior border forms an angle, the *parietal notch*, with the mastoid portion of the bone. The *sphenoidal* or *antero-inferior border*, thin above and thick below, articulates with the great wing of the sphenoidal bone ; its upper part is bevelled at the expense of the inner surface, its lower at the expense of the outer surface.

The mastoid portion forms the posterior part of the bone. Its *outer surface* (fig. 295) is rough, and gives attachment to the Occipitalis and Auricularis posterior. It is frequently perforated near the posterior border by the *mastoid foramen* which transmits a vein from the transverse sinus and a small branch of the occipital artery to the dura mater; the position and size of this foramen are very variable; it may be situated in the occipital bone, or in the suture between the temporal and the occipital. The mastoid portion is continued below into a conical projection, the *mastoid process*, the size and form of which vary somewhat; it is larger in the male than in the female. This process serves for the attachment of the Sternocleidomastoideus, Splenius capitis, and Longissimus capitis; on its medial side is a deep groove, the *mastoid notch*

FIG. 296.—Left temporal bone. Internal surface.



(*digastric fossa*), for the attachment of the posterior belly of the Digastricus; medial to this notch is a shallow furrow, the *occipital groove*, which lodges the occipital artery.

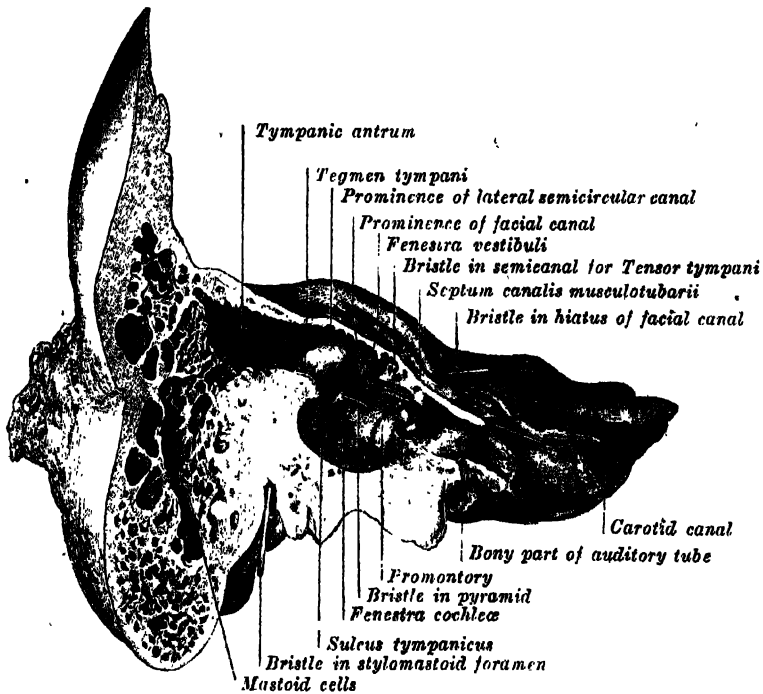
On the *inner surface* of the mastoid portion is a deep, curved groove, the *sulcus sigmoideus*, which lodges part of the transverse sinus; in it may be seen the opening of the mastoid foramen. The sulcus sigmoideus is separated from the innermost of the mastoid air-cells by a thin lamina of bone which may be partly deficient.

The *superior border* of the mastoid portion is thick and serrated for articulation with the mastoid angle of the parietal bone. The *posterior border*, also serrated, articulates with the inferior border of the occipital bone between the lateral angle and jugular process. Anteriorly the mastoid portion is fused with the descending process of the squama above; below it enters into the formation of the external acoustic meatus and the tympanic cavity.

A section of the mastoid process (fig. 297) exhibits a number of spaces, the *mastoid cells*, which vary greatly in size and number. At the upper and front part of the process they are large and irregular and contain air, but towards the lower part they diminish in size, while those at the apex of the

process are frequently quite small ; occasionally they are entirely absent, and the mastoid is then solid throughout. In addition to the mastoid cells a large irregular cavity, the *tympanic antrum*, is situated in the upper and front part of the bone ; it is filled with air and lined by a prolongation of the mucous membrane of the tympanic cavity. It is bounded above by a thin plate of bone, the *tegmen tympani*, which separates it from the middle fossa of the base of the skull ; laterally by the squama just below the temporal line ; medial to it is the lateral semicircular canal of the internal ear which projects into its cavity ; below and behind, it communicates with the mastoid air-cells. It opens in front into that portion of the tympanic cavity which is known as the *attic* or *epitympanic recess*. The tympanic antrum is a cavity of some considerable size at the time of birth ; the mastoid air-cells originate as diverticula

FIG. 207.—Coronal section of right temporal bone.



from the antrum, and begin to appear at or before birth ; by the fifth year they are well marked, but their development is not completed until towards puberty.

The **petrous portion** or **pyramid** is wedged between the sphenoidal and occipital bones at the base of the skull. It is directed medialwards, forwards, and a little upwards, and has a base, an apex, three surfaces, and three angles ; the essential parts of the organs of hearing and equilibration are placed within it.

The **base** is fused with the squama and the mastoid portion.

The **apex**, rough and uneven, is received into the angular interval between the posterior border of the great wing of the sphenoidal bone and the basilar part of the occipital bone ; it is pierced by the anterior or internal orifice of the carotid canal, and forms the posterolateral boundary of the foramen lacerum.

The **anterior surface** forms the posterior part of the middle fossa of the skull, and is continuous with the inner surface of the squama, to which it is united by the *petrosquamous suture*, remains of which are distinct even at a late period of life. It is marked by depressions for the convolutions of the brain, and presents six points for examination : (1) near the centre is the *eminencia acuta* which indicates the situation of the superior semicircular canal ; (2) in front of and a little lateral to this eminence is a depressed area

which forms the roof of the tympanic cavity and consists of a thin plate of bone known as the *tegmen tympani*; a thin scale of this descends between the squama and the tympanic plate, and forms the anterior boundary of the petrotympanic fissure, and the greater part of the lateral wall of the semicanal for the *Tensor tympani* muscle; (3) a shallow groove, sometimes double, leads backwards and lateralwards to an oblique opening, the *hiatus of the facial canal*, for the passage of the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery; (4) lateral to the hiatus there is occasionally a smaller opening for the passage of the lesser superficial petrosal nerve; (5) near the apex of the bone is the termination of the carotid canal, the anterior wall of which is here deficient; (6) above this canal is the shallow *trigeminal impression* for the reception of the semilunar ganglion of the trigeminal nerve.

The *posterior surface* (fig. 296) forms the anterior part of the posterior fossa of the skull, and is continuous with the inner surface of the mastoid portion. Near the centre is an orifice of varying size, the *porus acusticus internus* leading into the *internal acoustic meatus*, a short canal, about 1 cm. in length, which runs lateralwards. It transmits the facial and acoustic nerves and the internal auditory branch of the basilar artery. The lateral end of the internal acoustic meatus is closed by a vertical plate which separates it from the internal ear. This plate is divided by a horizontal crest, the *crista transversa*, into two unequal portions, each of which (fig. 298) is subdivided by a vertical ridge into an anterior and a posterior part. In the portion beneath the *crista transversa* are three sets of foramina: one group, below the posterior part of the crest, and situated in the *area vestibularis inferior*, consists of several small openings for the transmission of the nerves to the sacculæ; below and behind this area is the *foramen singulare*, which gives passage to the nerve to the posterior semicircular duct; in front of and below the *area vestibularis inferior* is the *tractus spiralis foraminosus*, consisting of a number of small spirally arranged openings, which encircle the *canalis centralis cochleæ*; these openings together with the *canalis centralis cochleæ* transmit the nerves to the cochlea. The portion above the *crista transversa* displays behind, the *area vestibularis superior*, pierced by a series of small openings for the passage of the nerves to the utricle and the superior and lateral semicircular ducts, and, in front, the *area facialis*, with one large opening which is the commencement of the *canalis facialis* (aqueductus Fallopii) and transmits the facial nerve. Behind the *porus acusticus internus* is a small slit almost hidden by a thin plate of bone, leading to a canal, the *aqueductus vestibuli*, which contains the ductus endolymphaticus together with a small artery and vein. Above and between these two openings is an irregular depression which lodges a process of the dura mater and transmits a small vein; in the infant this depression is represented by a large fossa, the *fossa subarcuata*, which extends backwards as a short blind tunnel under the superior semicircular canal.

The *inferior surface* (fig. 299), rough and irregular, forms part of the external surface of the base of the skull. It presents the following parts for examination: (1) near the apex is a quadrilateral rough surface, which serves partly for the attachment of the *levator veli palatini* and the cartilaginous portion of the auditory tube, and partly for connexion with the basilar part of the occipital bone through the intervention of some dense fibrous tissue; (2) behind

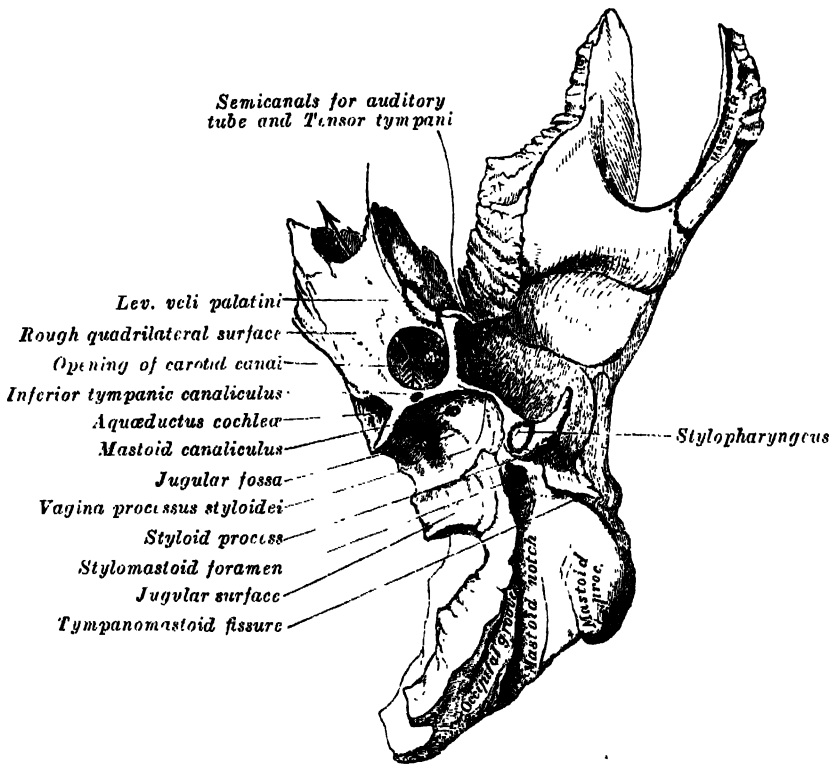
FIG. 298.—Diagrammatic view of the lateral end of the right internal acoustic meatus. (Testut.)



1. Crista transversa. 2. Area facialis, with (2') internal opening of the facial canal. 3. Ridge separating the area facialis from the area vestibularis superior. 4. Area vestibularis superior, with (4') openings for nerve filaments. 5, 5'. Tractus spiralis foraminosus, and (5') the canalis centralis of the cochlea. 6. Ridge separating the tractus spiralis foraminosus from the area vestibularis inferior. 7. Area vestibularis inferior, with (7') orifices for nerves to sacculæ. 8. Foramen singulare.

this is the large, nearly circular aperture of the *carotid canal*; this canal at first is vertical, and then, making a bend, runs horizontally forwards and medialwards; it transmits into the cranium the internal carotid artery, and the carotid plexus of nerves; (3) behind these openings is a deep depression, the *jugular fossa*, of variable depth and size in different skulls; it lodges the bulb of the internal jugular vein; (4) in front of the medial part of the jugular fossa and directly below the internal acoustic meatus is a triangular depression; at the apex of this depression is a small opening, the *aquæductus cochleæ*, which lodges a tubular prolongation of the dura mater and transmits a vein from the cochlea to join the internal jugular vein; (5) in the bony ridge dividing the carotid canal from the jugular fossa is the small *inferior tympanic canaliculus* for the passage of the tympanic branch of the glossopharyngeal nerve (nerve

FIG. 299.—Left temporal bone. Inferior surface.



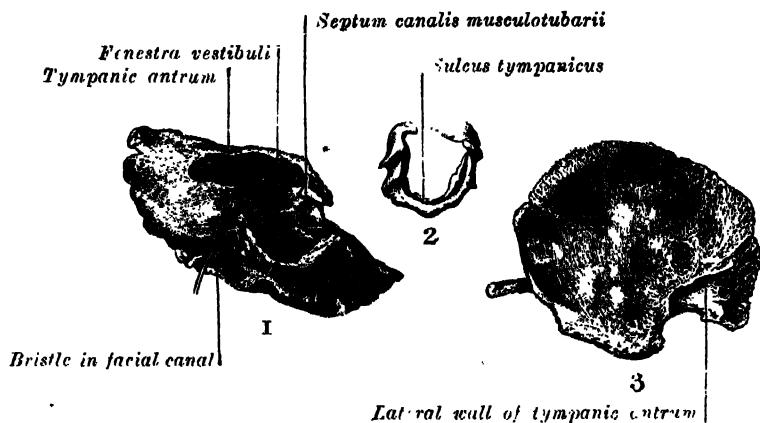
of Jacobson); (6) in the lateral part of the jugular fossa is the *mastoid canaliculus* for the entrance of the auricular branch of the vagus nerve (nerve of Arnold); (7) behind the jugular fossa is the *jugular surface*, a rough quadrilateral area covered with cartilage in the recent state, and articulating with the jugular process of the occipital bone; (8) extending lateralwards from the carotid canal is the sharp lower border of the tympanic part of the bone; the lateral part of this border splits to ensheath the root of the styloid process and is therefore named the *vagina processus styloidei*; (9) emerging from its sheath is the *styloid process*, which is about 2.5 cm. in length, and is directed downwards and forwards; (10) between the styloid and mastoid processes is the *stylomastoid foramen*; it is the termination of the facial canal, and transmits the facial nerve and stylomastoid artery.

The *superior angle* (superior margin), the longest, is grooved for the superior petrosal sinus, and gives attachment to the tentorium cerebelli; at its medial extremity is a shallow notch, in which the trigeminal nerve lies. The *posterior angle* (posterior margin) is intermediate in length between the superior and the anterior. Its medial part is marked by a sulcus, which forms, with a

corresponding sulcus on the occipital bone, the channel for the inferior petrosal sinus. Behind this is the *jugular fossa* which, with the jugular notch on the occipital bone, forms the jugular foramen; an eminence occasionally projects from the centre of the fossa, and divides the foramen into two. The *anterior angle* (anterior margin) is divided into two parts—a lateral, joined to the squama at the *petrosquamous suture*; a medial, free for articulation with the *spina angularis* of the sphenoidal bone.

At the angle of junction of the petrous part and the squama are two canals placed one above the other, and separated by a thin plate of bone, the *septum canalis musculotubarii* (*processus cochleariformis*). Both canals lead into the tympanic cavity; the upper (*semicanalis m. tensoris tympani*) transmits the Tensor tympani muscle, the lower (*semicanalis tubæ auditivæ*) forms the bony part of the auditory tube.

FIG. 300.—The three principal parts of the right temporal bone at birth.



1. Outer surface of petromastoid part. 2. Inner surface of tympanic ring. 3. Inner surface of squama.

The **tympanic part** is a curved plate of bone lying below the squama and in front of the mastoid process. Its *posterosuperior surface* is concave, and forms the anterior wall, the floor, and part of the posterior wall of the bony external acoustic meatus; at the medial end of this surface is a narrow furrow, the *tympanic sulcus*, for the attachment of the circumference of the tympanic membrane. Its *antero-inferior surface* is quadrilateral and slightly concave; it constitutes the posterior wall of the mandibular fossa, and is sometimes in contact with a part of the parotid gland. Its *lateral border* is free and rough, and gives attachment to the cartilaginous part of the external acoustic meatus. Internally, the tympanic part is fused with the petrous portion, and appears in the retreating angle between it and the squama, where it lies below and lateral to the orifice of the auditory tube. Posteriorly, it blends with the squama and mastoid part, and forms the anterior boundary of the tympanomastoid fissure. The lateral part of the *upper border* is fused with the back of the postglenoid process; its medial part forms the posterior boundary of the petrotympanic fissure. The medial part of the *lower border* is sharp; the lateral part splits to enclose the root of the styloid process, and is therefore named the *vagina processus styloidei*. The central portion of the tympanic part is thin, and in a considerable percentage of skulls is perforated by the *foramen of Huschke*.

The *external acoustic meatus*, nearly 2 cm. long, is directed inwards and slightly forwards and downwards, so that the floor of the meatus is convex upwards. In sagittal section it is oval or elliptical in shape with the long axis directed downwards and slightly backwards. Its anterior wall and floor and the lower part of its posterior wall are formed by the tympanic part of the bone; the roof and the upper part of the posterior wall by the squama. Its inner end is closed, in the recent state, by the tympanic membrane; its outer end (*porus*

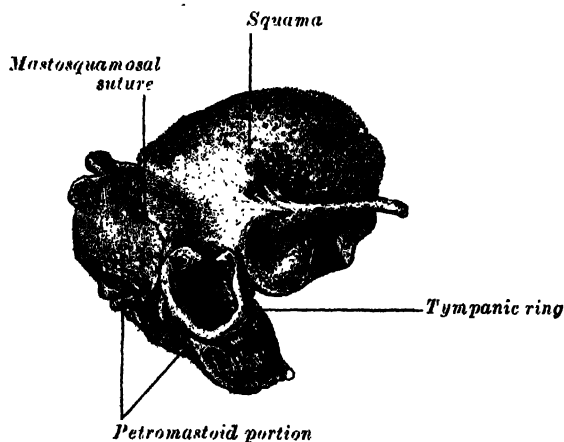
acusticus externus) is bounded above by the posterior root of the zygomatic process, below which a small spine, the *supramental spine*, is sometimes seen at the upper and posterior part of the orifice.

The **styloid process**, slender, pointed, and averaging about 2.5 cm. in length, projects downwards and forwards, from the under surface of the temporal bone. Its proximal part (*tympanohyal*) is surrounded by its sheath (*vagina processus styloidei*), while its distal part (*stylohyal*) gives attachment to the stylohyoid and stylomandibular ligaments, and to the Styloglossus, Stylohyoideus and Stylopharyngeus muscles.

Structure.—The structure of the squama is like that of the other cranial bones : the mastoid portion is spongy, and the petrous portion dense and hard.

Ossification.—The temporal bone is ossified from eight centres (exclusive of those for the internal ear and the tympanic ossicles)—viz. one for the squama, one for the tympanic part, four for the petrous and mastoid parts, and two for the styloid process. Just before the close of foetal life the bone consists of three principal parts, viz. : the squama, the petromastoid part, and the tympanic ring (fig. 300). The *squama* is ossified in membrane from a single nucleus which appears near the root of the zygomatic process about the seventh or eighth week of foetal life. The *petromastoid* part is developed from four centres, which make their appearance in the cartilaginous ear-capsule (page 75) about the fifth or sixth month. One (*pro-otic*) appears in the neighbourhood of the eminentia arcuata, spreads in front of and above the internal acoustic meatus and extends to the apex of the bone ; it forms part of the cochlea, vestibule, superior semicircular canal, and medial wall of the tympanic cavity. A second (*opisthotic*) appears at the promontory on the medial wall of the tympanic cavity and surrounds the fenestra cochleæ ; it forms the floor of the tympanic cavity and vestibule, surrounds the carotid canal, invests the lateral and lower part of the cochlea, and spreads medially below the internal acoustic meatus. A third (*pterotic*) roofs in the tympanic cavity and antrum ; while the fourth (*epiotic*) appears near the posterior semicircular canal and extends to form the mastoid process (Vrolik). The *tympanic ring* is an incomplete circle in the concavity of which is a groove, the tympanic sulcus, for the attachment of the circumference of the tympanic membrane. This ring expands to form the

FIG. 301.—Temporal bone at birth. Outer aspect.



tympanic part, and is ossified in membrane from a single centre which appears about the third month.* The *styloid process* is developed from the proximal part of the cartilage of the second branchial or hyoid arch by two centres : one for the proximal part, the *tympanohyal*, appears before birth ; the other, comprising the rest of the process, is named the *stylohyal*, and does not appear until after birth. The tympanic ring unites with the squama shortly before birth ; the petromastoid part and the squama join

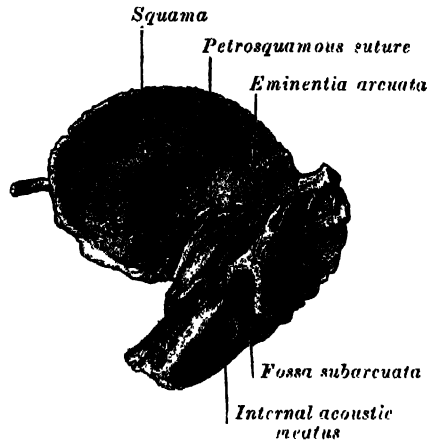
during the first year, and the tympanohyal portion of the styloid process about the same time (figs. 301, 302). The stylohyal does not unite with the rest of the bone until after puberty, and in some skulls never at all.

The chief subsequent changes in the temporal bone apart from increase in size are : (1) The tympanic ring extends lateralwards and backwards to form the tympanic part of the bone. This extension does not, however, take place at an equal rate all round the circumference of the ring, but occurs most rapidly on its anterior

* Two crests, the *superior* and *inferior tympanic crests*, run obliquely downwards and forwards across the anterior part of the inner surface of the tympanic ring. Between them is an obliquely directed furrow, the *sulcus malleolaris*, which lodges the anterior process of the malleus. The anterior tympanic artery and the chorda tympani nerve.

and posterior portions, and these outgrowths meet and blend, and thus, for a time, there exists in the floor of the meatus a foramen, the *foramen of Huschke*; this foramen is usually closed about the fifth year, but may persist throughout life. (2) The mandibular fossa is at first extremely shallow, and looks more lateralwards than downwards: it becomes deeper and is ultimately directed downwards. Its change in direction is accounted for as follows. The part of the squama which forms the fossa lies at first below the level of the zygomatic process and is nearly vertical, but in consequence of the subsequent increase in the width of the base of the skull this part of the squama comes to be directed horizontally inwards, and its surfaces therefore upwards and downwards; the attached portion of the zygomatic process also becomes everted and projects like a shelf at right angles to the squama. (3) The mastoid portion is at first quite flat, and the stylo-mastoid foramen and rudimentary styloid process lie immediately behind the tympanic ring. With the development of the mastoid air-cells the outer part of the mastoid portion grows downwards and forwards to form the mastoid process, and the styloid process and stylo-mastoid foramen come to lie on the under surface of the bone. The descent of the stylo-mastoid foramen is necessarily accompanied by a corresponding increase in the length of the facial canal. (4) The downward and forward growth of the mastoid process also pushes forward the tympanic part, so that the portion of the latter which formed the original floor of the meatus and contained the foramen of Huschke ultimately constitutes the anterior wall of the meatus. (5) The fossa subarcuata on the posterior surface of the petrous portion becomes filled up and almost obliterated.

FIG. 302.—Temporal bone at birth.
Inner aspect.



THE PARIETAL BONES (OSSA PARIETALIA)

The **parietal bones** form, by their union, the sides and roof of the cranium. Each is irregularly quadrilateral in shape, and has two surfaces, four borders, and four angles.

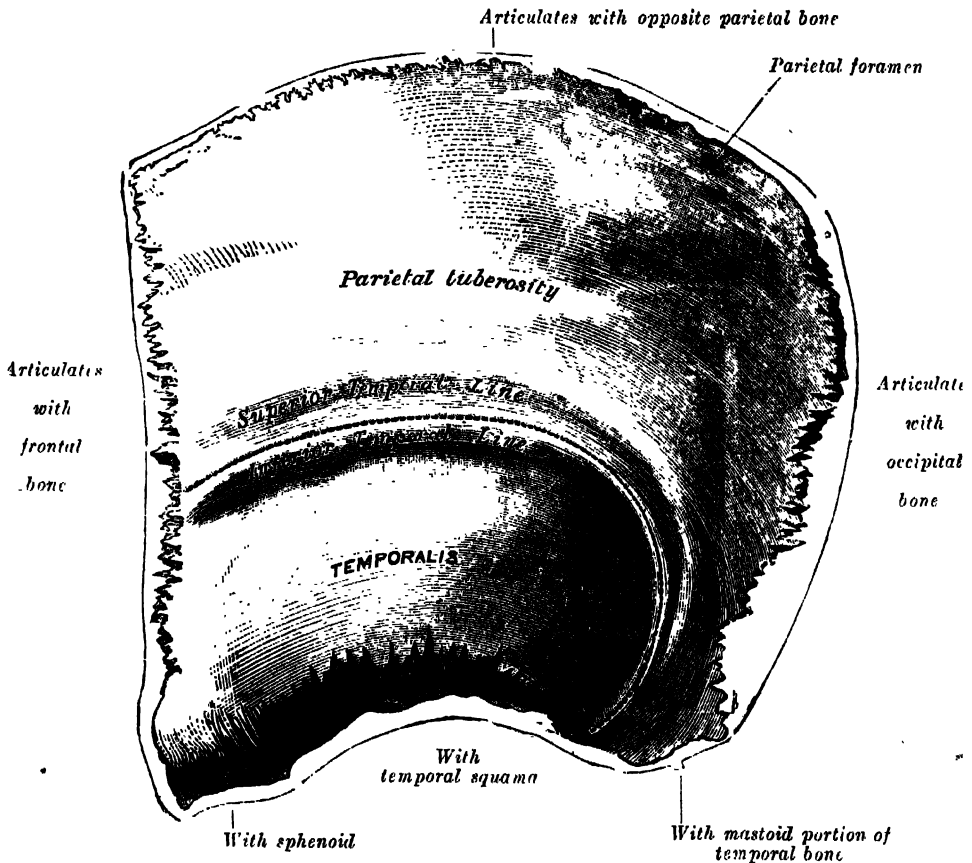
The *parietal* or *external surface* (fig. 303) is convex, smooth, and marked near the centre by an eminence, the *parietal tuberosity* or *eminence*. Crossing the middle of the bone in an arched direction are two curved lines, the *superior* and *inferior temporal lines*; the former gives attachment to the temporal fascia, and the latter indicates the upper limit of the origin of the Temporalis. Above these lines the bone is covered by the galea aponeurotica; below them it forms part of the temporal fossa. At the posterior part and close to the upper or sagittal border is the *parietal foramen*, which transmits a vein from the superior sagittal sinus, and sometimes a small branch of the occipital artery; the foramen is not constantly present, and its size varies considerably.

The *cerebral* or *internal surface* (fig. 304) is concave; it presents depressions corresponding to the cerebral convolutions, and numerous furrows for the ramifications of the middle meningeal vessels*; the latter run upwards and backwards from the sphenoidal angle, and from the central and posterior part of the squamous border. Along the upper or sagittal border is a shallow groove, which, with that on the opposite parietal, forms the *sagittal sulcus*, for the superior sagittal sinus; to the edges of the sulcus the falx cerebri is attached. Near the sulcus are several depressions, best marked in the skulls of old persons, for the arachnoidal granulations (*glandulae Pacchionii*).

* Consult articles by F. Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvii, and B. Coen, *Journal of Anatomy and Physiology*, vol. xlviii.

The *sagittal border*, the longest and thickest, is dentated and articulates with its fellow of the opposite side, to form the sagittal suture. The *squamous border* is divided into three parts: of these, the anterior is thin and pointed, bevelled at the expense of the external surface, and overlapped by the tip of the great wing of the sphenoidal bone; the middle portion is arched, bevelled at the expense of the external surface, and overlapped by the squama of the temporal bone; the posterior part, thick and serrated, articulates with the mastoid portion of the temporal bone. The *frontal border* is deeply serrated,

FIG. 303.—Left parietal bone. External surface.



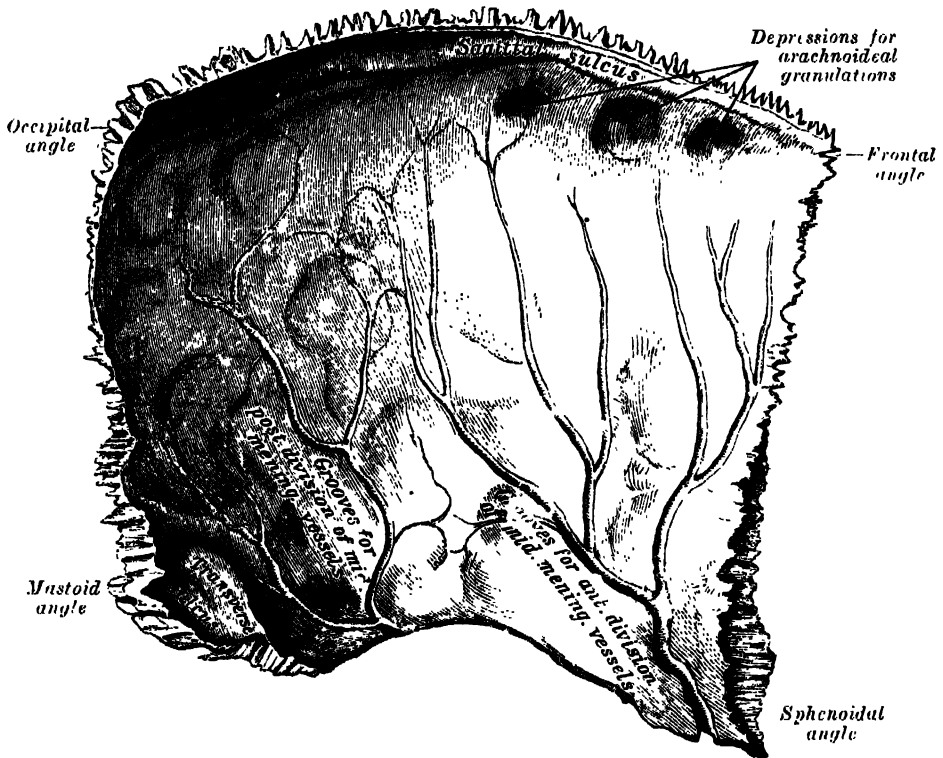
and bevelled at the expense of the external surface above and of the internal below; it articulates with the frontal bone, forming one half of the coronal suture. The *occipital border*, deeply dentated, articulates with the occipital bone, forming one half of the lambdoidal suture.

The *frontal angle* is practically a right angle, and corresponds with the point of meeting of the sagittal and coronal sutures; this point is named the *bregma*; in the foetus and for about a year and a half after birth this region of the skull is membranous, and is called the *frontal fonticulus* (anterior fontanelle). The *sphenoidal angle*, thin and acute, is received into the interval between the frontal bone and the great wing of the sphenoidal bone; in some cases the frontal bone articulates with the squama of the temporal bone, and the parietal then fails to reach the great wing of the sphenoidal bone. Its internal surface is marked by a deep groove, sometimes a canal, for the anterior divisions of the middle meningeal vessels. The *occipital angle* is rounded and corresponds with the *lambda* or point of meeting of the sagittal and lambdoidal sutures; in the foetus, and for about a year after birth, this part of the skull is membranous, and is called the *occipital fonticulus* (posterior fontanelle). The *mastoid angle*

is blunt and articulates with the occipital bone and with the mastoid portion of the temporal bone; on its internal surface is a broad, shallow groove, the transverse sulcus, which lodges a small part of the transverse sinus.

Ossification.—The parietal bone is ossified in membrane from two centres, which appear one above the other at the parietal tuberosity about the seventh week of foetal life. These centres unite early, and ossification gradually extends in a radial manner towards the margins of the bone; the angles are consequently the parts last formed, and it is here that the fonticuli exist. At birth the temporal

FIG. 304.—Left parietal bone. Internal surface.



lines are situated low down; they only reach their permanent position after the eruption of the molar teeth. Occasionally the parietal bone is divided into two parts, upper and lower, by an anteroposterior suture.

THE FRONTAL BONE (OS FRONTALE)

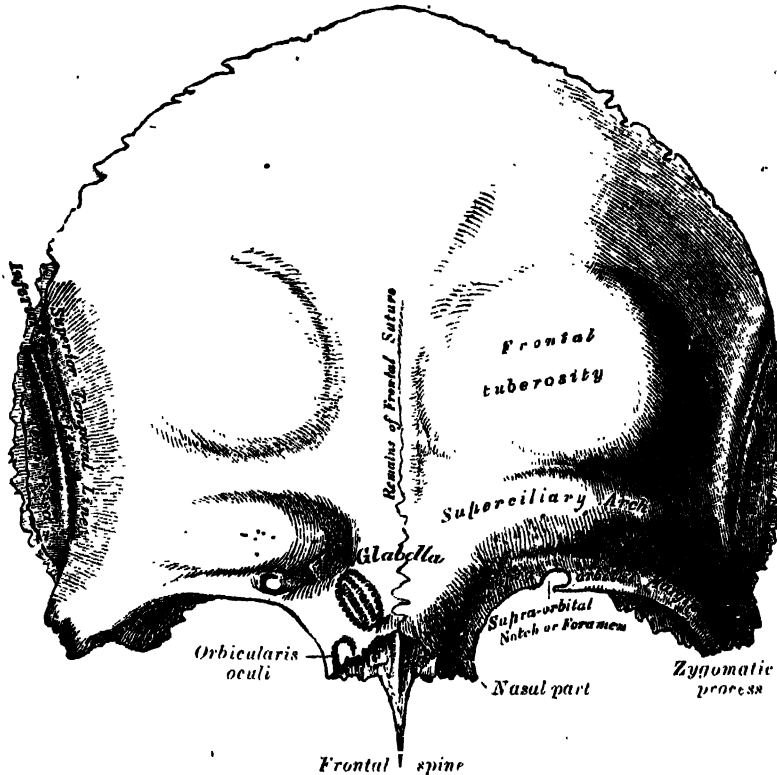
The frontal bone resembles a cockle-shell in form, and consists of two portions—a vertical part, the *squama*, corresponding with the region of the forehead; and a horizontal or *orbital* part, which enters into the formation of the roofs of the orbital and nasal cavities.

Squama.—The *external surface* of the squama (fig. 305) is convex and divided into a large frontal and two small temporal surfaces by lines which arch backwards across the lateral parts of the bone.

The *frontal surface* usually exhibits, in the lower part of the middle line, the remains of the *frontal* or *metopic suture*; in infancy this suture divides the bone into two, a condition which persists in about 9 per cent. of skulls. On either side of this suture, about 3 cm. above the supraorbital margin, is a rounded elevation, the *frontal tuberosity* or *eminence*. These tuberosities vary in size in different individuals, are occasionally unsymmetrical, and are especially prominent in young skulls; the surface of the bone above them is smooth, and covered by the *galea aponeurotica*. Below the frontal tuberosities, and separated from them by a shallow groove, are two curved elevations, the

superciliary arches, the medial parts of which are prominent, and joined to one another by a smooth elevation named the *glabella*. These arches are larger in the male than in the female, and their degree of prominence depends to some extent on the size of the frontal air-sinuses; prominent ridges are, however, occasionally associated with small air-sinuses. Beneath the superciliary arches are the curved *supraorbital margins*, which form the upper boundaries of the bases of the orbits, and separate the squama from the orbital portion of the bone. The lateral two-thirds of each supraorbital margin are sharp; the medial third is rounded. At the junction of these two parts is the *supraorbital notch* or *foramen* which transmits the supraorbital vessels and nerve. Medial

FIG. 305.—Frontal bone. External surface.



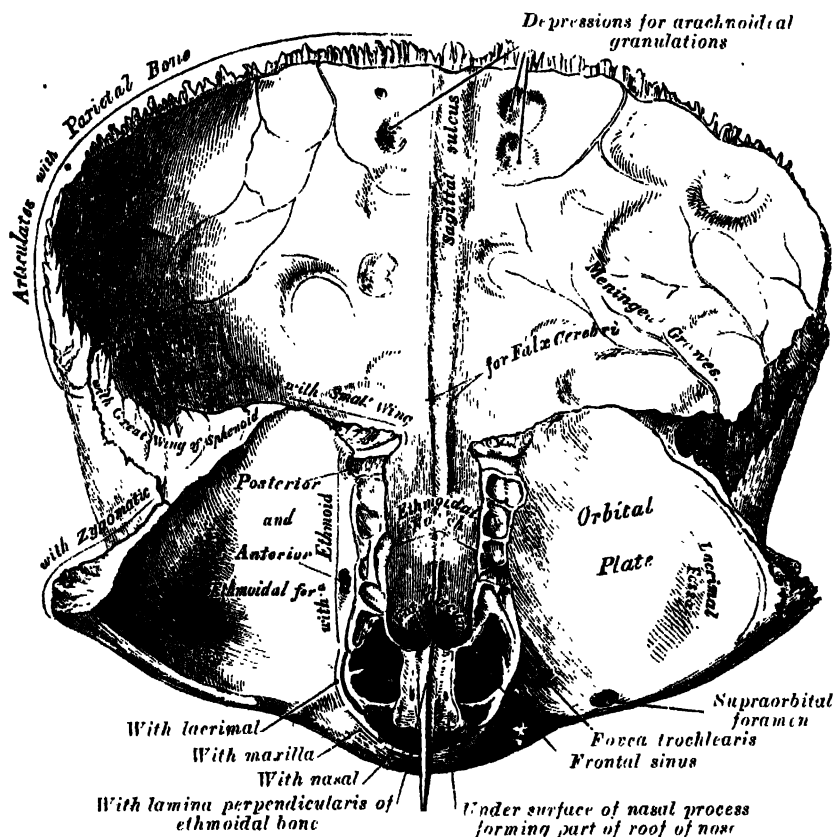
to this foramen is the small *frontal notch* or *foramen*. The supraorbital margin ends laterally in the *zygomatic process*, which is strong and prominent, and articulates with the zygomatic bone. Running upwards and backwards from this process is a line which soon divides into the *superior and inferior temporal lines*.

The portion of the squama which projects downwards between the supra-orbital margins is known as the *nasal part*. It presents a rough, uneven interval, the *nasal notch*, which articulates on either side of the middle line with the nasal bone, and lateral to this with the frontal process of the maxilla and with the lacrimal. From the centre of the notch the *nasal process* projects downwards and forwards beneath the nasal bones and frontal processes of the maxillæ, and supports the bridge of the nose. The nasal process ends below in a sharp *frontal spine*, and on either side of this is a small grooved surface which forms part of the roof of the corresponding nasal cavity. The frontal spine forms part of the septum of the nose; it articulates in front with the crest of the nasal bones, behind with the lamina perpendicularis of the ethmoidal bone.

The *temporal surface*, below and behind the temporal lines, forms the anterior part of the temporal fossa, and gives origin to the Temporalis muscle.

The *cerebral surface* (fig 306) of the squama is concave. In the upper part of the middle line is a vertical groove, the *sagittal sulcus*, the edges of which unite below to form the *frontal crest*; the sulcus lodges the anterior part of the superior sagittal sinus, while its margins and the crest afford attachment to the anterior part of the *falx cerebri*. The crest ends below in a small notch which is converted into the *foramen cæcum* by articulation with the ethmoidal bone. The foramen cæcum varies in size in different skulls, and is frequently impervious; when open, it transmits a vein from the nose to the superior sagittal sinus. On either side of the middle line are depressions for the convolutions of the brain, and minute furrows for the anterior branches of

FIG. 306.—Frontal bone. Cerebral surface.



the middle meningeal vessels. Several small, irregular fossæ may be seen on either side of the sagittal sulcus, for the reception of the arachnoidal granulations.

The *border of the squama* is thick, strongly serrated, bevelled at the expense of the cerebral surface above, where it rests upon the parietal bones, and at the expense of the temporal surface on either side, where it receives the lateral pressure of those bones; it is continued below into a triangular, rough surface, which articulates with the great wing of the sphenoid.

Orbital part.—This part consists of two thin triangular *orbital plates*, which form the vaults of the orbits, and are separated from one another by a wide gap, the *ethmoidal notch*.

The *orbital surface* (fig. 306) of each orbital plate is smooth and concave, and presents, laterally, under cover of the zygomatic process, a shallow depression, the *lacrimal fossa*, for the lacrimal gland; below and behind the medial end of the supraorbital margin is a depression, the *fovea trochlearis*, or occasionally a small *spina trochlearis*, for the attachment of the fibrocartilaginous pulley

of the *Obliquus oculi superior*. The *cerebral surface* is convex, and marked by depressions corresponding to the convolutions of the frontal lobe of the brain, and faint grooves for the meningeal branches of the ethmoidal vessels.

The *ethmoidal notch* (*incisura ethmoidalis*) separates the two orbital plates; it is quadrilateral, and filled, in the articulated skull, by the *lamina cribrosa* of the ethmoidal bone. On the margins of the notch are several half-cells which, when united with corresponding half-cells on the upper surface of the ethmoidal bone, complete the ethmoidal air-cells. Two grooves cross each margin transversely; they are converted into the *anterior* and *posterior ethmoidal canals* by the ethmoidal bone, and open on the medial wall of the orbit. They transmit the anterior and posterior ethmoidal nerves and vessels. In front of the ethmoidal notch, and lateral to the frontal spine, are the openings of the *frontal air-sinuses*. These sinuses are two irregular cavities, which extend backwards, upwards, and lateralwards for a variable distance between the two tables of the bone; they are separated from one another by a thin bony septum, which is often deflected to one or other side of the middle line, with the result that the sinuses are seldom symmetrical. Rudimentary at birth, they are usually fairly well developed between the seventh and eighth years, but only reach their full development after puberty. They vary in size in different persons, and are larger in men than in women.* Each communicates with the middle meatus of the corresponding nasal cavity by means of a passage called the *frontonasal duct*.

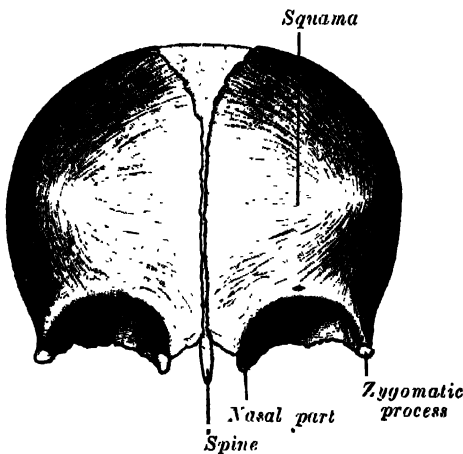
The *posterior borders* of the *orbital plates* are thin and serrated, and articulate with the small wings of the sphenoidal bone; the lateral part of each usually appears in the middle fossa of the skull between the great and small wings of the sphenoidal bone.

Structure.—The squama and the zygomatic processes are thick and consist of spongy substance contained between two compact laminae; the spongy substance

is absent in the regions occupied by the frontal air-sinuses. The orbital part, composed entirely of compact bone, is thin and translucent, hence the facility with which the cranium can be penetrated through the roof of the orbit; when the frontal sinuses are exceptionally large they may extend backwards for a considerable distance into the orbital plates.

Ossification.—(fig. 307) The frontal bone is ossified in membrane from two *primary* centres which appear in the seventh or eighth week of foetal life, one above each supraorbital margin. From each of these centres ossification extends upwards to form

FIG. 307.—Frontal bone at birth.



the corresponding half of the squama, and backwards to form the orbital plate. The spine is ossified from a pair of *secondary* centres, one on either side of the middle line; similar centres appear in the nasal part and zygomatic processes. At birth the bone consists of two pieces separated by the frontal suture; union of the two pieces begins in the second year, and the frontal suture is usually obliterated, except at its lower part, by the eighth year.

* Logan Turner (*op. cit.*) gives the following measurements for a sinus of average size: height, 3.16 cm.; breadth, 2.58 cm.; depth from before backwards, 1.8 cm. Onodi (*op. cit.*) states that in infants of from one to twelve months the height of the frontal sinus varies from 3.5 mm. to 8 mm., and its width from 2 mm. to 6 mm., and that in the eighth year of life the height is from 14 mm. to 17 mm., and the width from 7 mm. to 9 mm.

THE ETHMOIDAL BONE (OS ETHMOIDALE)

The ethmoidal bone is cubical in shape, and exceedingly light; it is situated at the anterior part of the base of the cranium and assists in forming the medial walls of the orbital cavities and the roofs and lateral walls of the nasal cavities. It consists of four parts: a horizontal, perforated plate named the lamina cribrosa, a lamina perpendicularis, and two labyrinths or lateral masses.

The lamina cribrosa (fig. 308) occupies the ethmoidal notch of the frontal bone and helps to roof in the nasal cavities. Projecting upwards from the median line of this plate is a thick, smooth, triangular process, the *crista galli*, so called from its resemblance to a cock's comb. Its posterior border, long, thin, and curved, gives attachment to the falx cerebri. Its anterior border, short and thick, articulates with the frontal bone by two small projecting alar processes which complete the foramen cæcum. Its sides are smooth, and sometimes bulging from the presence of a small air-sinus in the interior. On either side of the crista galli, the lamina cribrosa is narrow and depressed; it supports the olfactory bulb and is perforated by foramina for the passage of the olfactory nerves. The foramina in its middle part are small and transmit the nerves to the roof of the nasal cavity; those in the medial and lateral parts are larger—the former transmit the nerves to the mucous membrane on the upper part

FIG. 308.—Ethmoidal bone, from above.

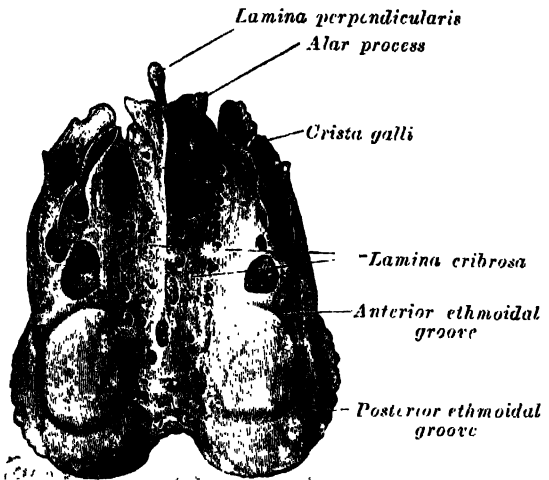
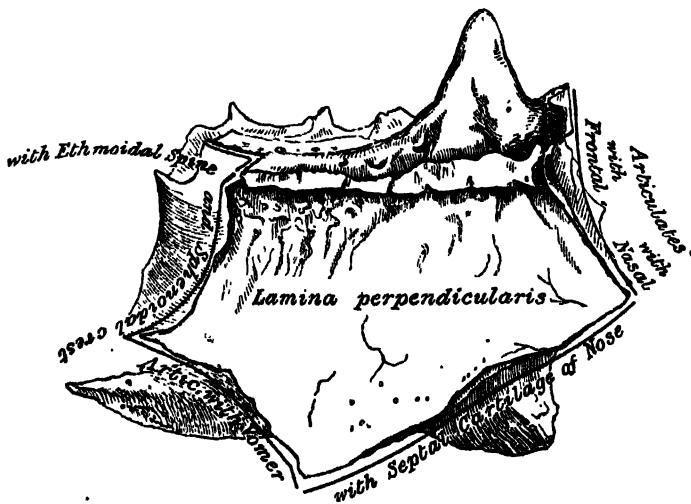


FIG. 309.—Lamina perpendicularis of ethmoidal bone. Shown by removing the right labyrinth.

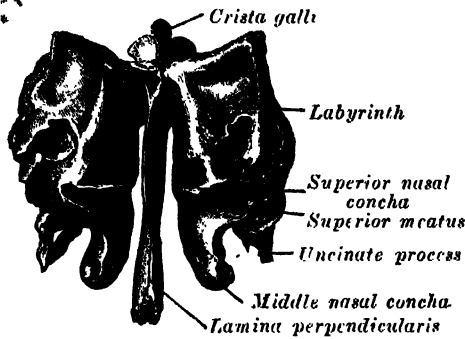


of the nasal septum, the latter the nerves to the mucous membrane on the superior nasal concha. At the front part of the lamina cribrosa, on either side of the crista galli, is a small fissure which is occupied by a process of dura mater.

Lateral to this fissure is a foramen which transmits the anterior ethmoidal nerve to the nasal cavity; from this foramen a groove runs backwards to the anterior ethmoidal foramen.

The lamina perpendicularis (figs. 309, 310), thin, flattened and polygonal in form, descends from the under surface of the lamina cribrosa, and forms the upper part of the nasal septum; it is generally deflected a little to one or other side. The anterior border articulates with the spine of the frontal bone and the crest of the nasal bones. The posterior border articulates with the sphenoidal crest above and with the vomer below. The inferior border is thick, and serves for the attachment of the cartilage of the septum of the nose. The surfaces of the lamina are smooth, except above, where numerous grooves and canals are seen; these lead from the medial foramina on the lamina cribrosa and lodge filaments of the olfactory nerves.

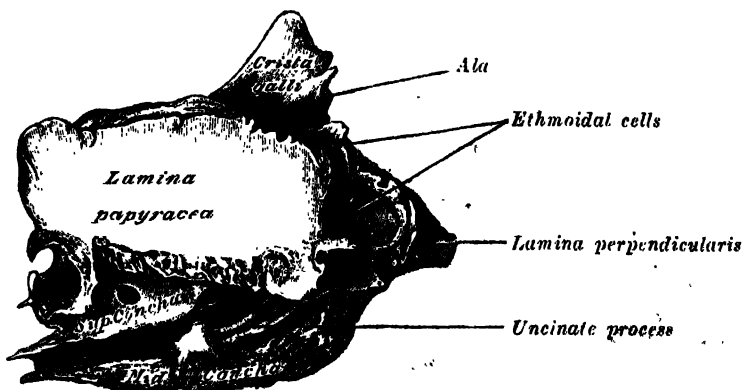
FIG. 310.—Ethmoidal bone, from behind.



The labyrinth or lateral mass consists of a number of thin-walled ethmoidal air-cells, arranged in three groups, anterior, middle, and posterior, and interposed between two vertical plates of bone; the lateral plate forms part of the medial wall of the orbit, the medial plate, part of the corresponding nasal cavity.* In the disarticulated bone many of these ethmoidal air-cells are open, but in the articulated skull they are everywhere closed, except at their openings into the nasal cavity. The upper surface of the labyrinth (fig. 308) presents a number of cells, the walls of which are completed, in the articulated skull, by the edges of the ethmoidal notch of the frontal bone. Crossing this surface are two grooves which are converted into the anterior and posterior ethmoidal canals by articulation with the frontal bone. On the posterior surface (fig. 310) are large air-cells the walls of which are completed by the sphenoidal concha above and the orbital process

below. The lateral surface (fig. 311) consists of a thin, smooth, oblong plate, the lamina papyracea (os planum), which covers in the middle and posterior ethmoidal cells and forms a large part of the medial wall of the orbit; it articulates above with the orbital plate of the frontal bone,

FIG. 311.—Ethmoidal bone, from the right side.



of the palatine bone below. The lateral surface (fig. 311) consists of a thin, smooth, oblong plate, the lamina papyracea (os planum), which covers in the middle and posterior ethmoidal cells and forms a large part of the medial wall of the orbit; it articulates above with the orbital plate of the frontal bone,

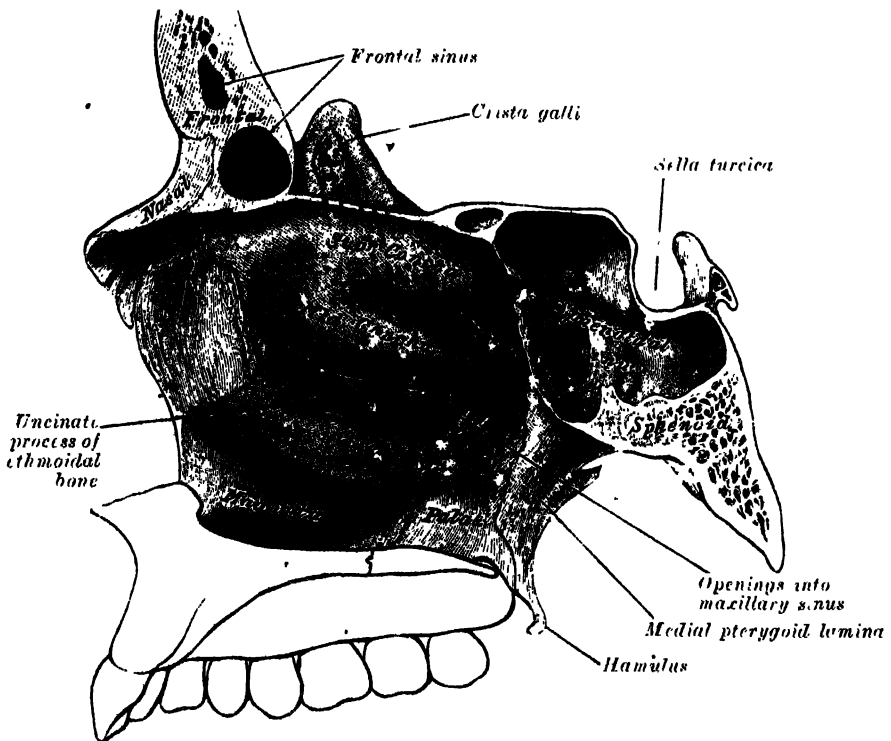
* Some anatomists divide the ethmoidal air-cells into two groups, an anterior, comprising the cells which open into the middle meatus of the nose, and a posterior, those which open into the superior meatus.

below with the maxilla and the orbital process of the palatine bone, in front with the lacrimal, and behind with the sphenoidal bone (fig. 324).

In front of the lamina papyracea are some air-cells, the walls of which are completed by the lacrimal bone and the frontal process of the maxilla. A curved lamina, the *uncinate process*, projects downwards and backwards from this part of the labyrinth; it forms a small part of the medial wall of the maxillary sinus (fig. 324), and articulates with the ethmoidal process of the inferior nasal concha.

The *medial surface* of the labyrinth (fig. 312) forms part of the lateral wall of the corresponding nasal cavity; it consists of a thin lamella, which descends from the under surface of the lamina cribrosa, and ends in a free, convoluted

FIG. 312.—Lateral wall of nasal cavity, showing the ethmoidal bone (coloured red) and the inferior nasal concha (coloured blue) in position.



margin, the *middle nasal concha*. Its upper part is marked by numerous grooves, directed nearly vertically downwards from the lamina cribrosa; they lodge branches of the olfactory nerves, which are distributed to the mucous membrane covering the superior nasal concha. The posterior part of the medial surface is subdivided by a narrow, oblique fissure, the *superior meatus of the nose*, bounded above by a thin, curved plate, the *superior nasal concha*; the posterior ethmoidal cells open into this meatus. Below and in front of the superior meatus is the convex surface of the middle nasal concha; it extends along the whole length of the medial surface of the labyrinth. Its lower margin is free and thick, while its lateral surface is concave, and assists in forming the *middle meatus of the nose*. The middle ethmoidal cells produce a rounded swelling, named the *bullae ethmoidales*, on the lateral wall of the middle meatus; on this bulla, or immediately above it, the cells open into the meatus. A curved passage, termed the *infundibulum*, extends upwards and forwards from the middle meatus; it communicates with the anterior ethmoidal cells, and in rather more than 50 per cent. of skulls is continued upwards as the frontonasal duct into the frontal sinus.

Ossification.—The ethmoidal bone is ossified in the cartilaginous nasal capsule by three centres; one for the lamina perpendicularis, and one for each labyrinth.

The centre for each labyrinth appears in the region of the lamina papyracea between the fourth and fifth months of foetal life, and extends into the conchæ. At birth, the bone consists of the two labyrinths, which are small and ill-developed. During the first year after birth, the lamina perpendicularis and crista galli begin to ossify from a single centre, and are joined to the labyrinths about the beginning of the second year. The lamina cribrosa is ossified partly from the lamina perpendicularis and partly from the labyrinths. The ethmoidal cells begin to develop during foetal life, and in the new-born infant have the form of narrow pouches.

THE INFERIOR NASAL CONCHÆ (CONCHÆ NASALES INFERIORES)

The inferior nasal conchæ are curved lamina which extend horizontally along the lateral walls of the nasal cavities (fig. 312). Each bone has two surfaces, two borders, and two extremities.

The *medial surface* (fig. 313) is convex, perforated by numerous apertures, and traversed by longitudinal grooves for the lodgment of vessels. The *lateral surface* is concave (fig. 314), and forms part of the inferior meatus of the nasal cavity. The *upper border* is thin and irregular, and may be divided into three

FIG. 313.—Right inferior nasal concha.
Medial surface.

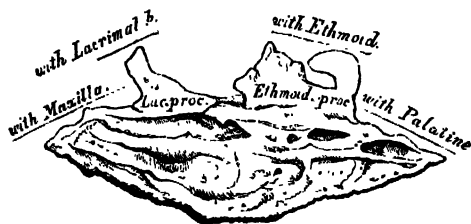
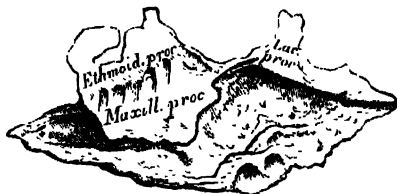


FIG. 314.—Right inferior nasal concha.
Lateral surface.



portions: of these, the anterior articulates with the crista conchalis of the maxilla, and the posterior with the crista conchalis of the palatine bone. The middle portion presents three processes, which vary much in their size and form. Of these, the *lacrimal process* is small and pointed and is situated at the junction of the anterior fourth with the posterior three-fourths of the bone: it articulates, by its apex, with the descending process of the lacrimal bone, and, by its margins, with the edges of the nasolacrimal groove on the medial surface of the body of the maxilla, and thus assists in forming the canal for the nasolacrimal duct. Behind this process a thin plate, the *ethmoidal process*, ascends to join the uncinate process of the ethmoid; from the middle part of the superior border a thin lamina, the *maxillary process*, curves downwards and lateralwards; it articulates with the maxilla and the maxillary process of the palatine bone, and forms a part of the medial wall of the maxillary sinus (fig. 324). The *inferior border* is free, thick, and spongy in structure, more especially in the middle of the bone. Both *extremities* are more or less pointed, the posterior being the more tapered.

Ossification.—The inferior nasal concha is ossified from a single centre; this appears about the fifth month of foetal life in the maxilloturbinal cartilage which is the incurved lower border of the lateral wall of the nasal capsule. It is detached from the remainder of the nasal capsule during ossification.

THE LACRIMAL BONES (OSSA LACRIMALIA)

The lacrimal bones, the smallest and most fragile of the cranial bones, are situated at the front parts of the medial walls of the orbits (fig. 316). Each bone has two surfaces and four borders. The *lateral or orbital surface* (fig. 315) is divided by a vertical ridge, the *posterior lacrimal crest*, into two parts. In

front of this crest is the *lacrimal groove*, the inner margin of which unites with the *frontal process of the maxilla* to complete the *lacrimal fossa*. The upper part of this fossa lodges the *lacrimal sac*; the lower, part of the *nasolacrimal duct*. The portion behind the crest is smooth, and forms part of the medial wall of the orbit. The crest, with a part of the orbital surface immediately behind it, gives origin to the *lacrimal part of the Orbicularis oculi*, and ends below in a small, hook-like projection, the *lacrimal hamulus*, which articulates with the *lacrimal tubercle of the maxilla* and completes the upper orifice of the *lacrimal canal*; the *lacrimal hamulus* sometimes exists as a separate piece, and is then called the *lesser lacrimal bone*. On the *medial or nasal surface* is a vertical furrow, corresponding to the posterior *lacrimal crest* on the lateral surface. The area in front of this furrow forms part of the *middle meatus of the nose*; that behind it articulates with the *ethmoidal bone*, and completes some of the anterior *ethmoidal air-cells*. Of the *four borders* the *anterior* articulates with the *frontal process of the maxilla*; the *posterior* with the *lamina papyracea of the ethmoidal bone*; the *superior* with the *frontal bone*. The *inferior* is divided by the lower edge of the posterior *lacrimal crest* into two parts: the *posterior part* articulates with the *orbital plate of the maxilla*; the *anterior* is prolonged downwards as the *descending process*, which articulates with the *lacrimal process of the inferior nasal concha* and with the edges of the *nasolacrimal groove on the maxilla*, and assists in forming the canal for the *nasolacrimal duct*.

FIG. 315.—Left lacrimal bone. Orbital surface. (Enlarged.)

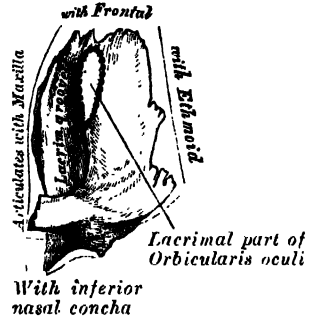
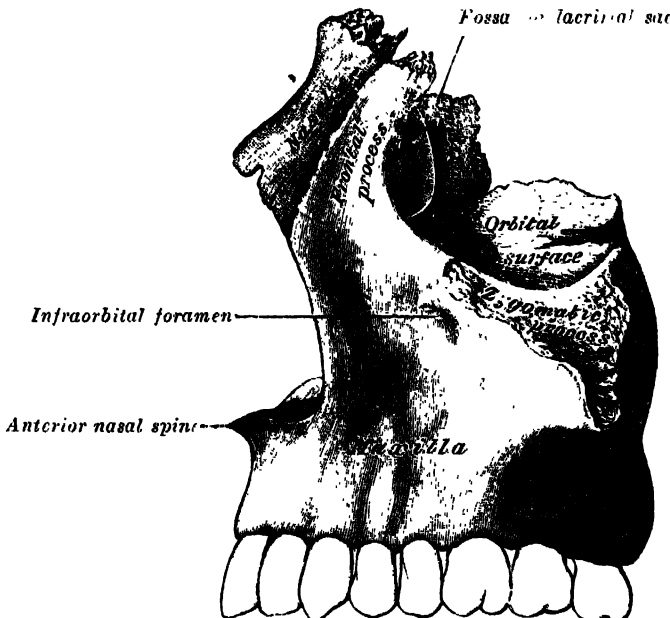


FIG. 316.—Articulation of nasal and lacrimal bones with maxilla.



Ossification.—The lacrimal is ossified from a single centre, which appears about the twelfth week of foetal life in the membrane covering the cartilaginous nasal capsule.

THE NASAL BONES (OSSA NASALIA)

The **nasal bones** are two small oblong bones, varying in size and form in different individuals; they are placed side by side between the frontal processes of the maxillæ, and form, by their junction, 'the bridge' of the nose (fig. 316).

Each has two surfaces and four borders. The *outer surface* (fig. 317) is concavo-convex from above downwards, convex from side to side; it is covered by the *Procerus* and *Compressor naris*, and is perforated near its centre by a foramen, for the transmission of a small vein. The *inner surface* (fig. 318) is concave from side to side, and is traversed from above downwards by a groove, the *ethmoidal sulcus*, for the passage of the *anterior ethmoidal nerve*. The *superior border*, thick and serrated, articulates with the nasal notch of the frontal bone. The *inferior border* is thin and notched, and gives attachment to the lateral cartilage of the nose. The *lateral border* articulates with the frontal process of the maxilla. The *medial border*, thicker above than below, articulates with its fellow of the opposite side, and is prolonged behind into a vertical crest which forms part of the septum of the nose: this crest articulates, from above downwards, with the *frontal spine*, the *lamina perpendicularis* of the ethmoidal bone, and the cartilage of the septum of the nose.

FIG. 317.—Right nasal bone.
Outer surface.

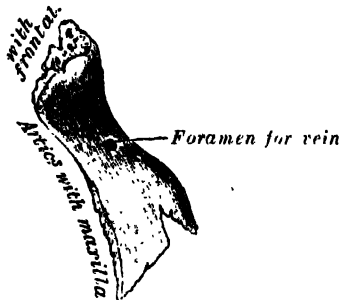
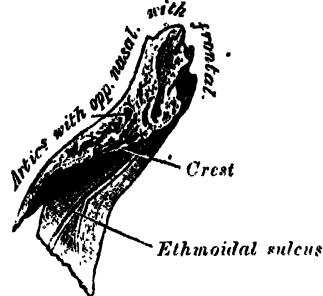


FIG. 318.—Right nasal bone.
Inner surface.



Ossification.—Each bone is ossified from one centre, which appears at the beginning of the third month of foetal life in the membrane overlying the front part of the cartilaginous nasal capsule.

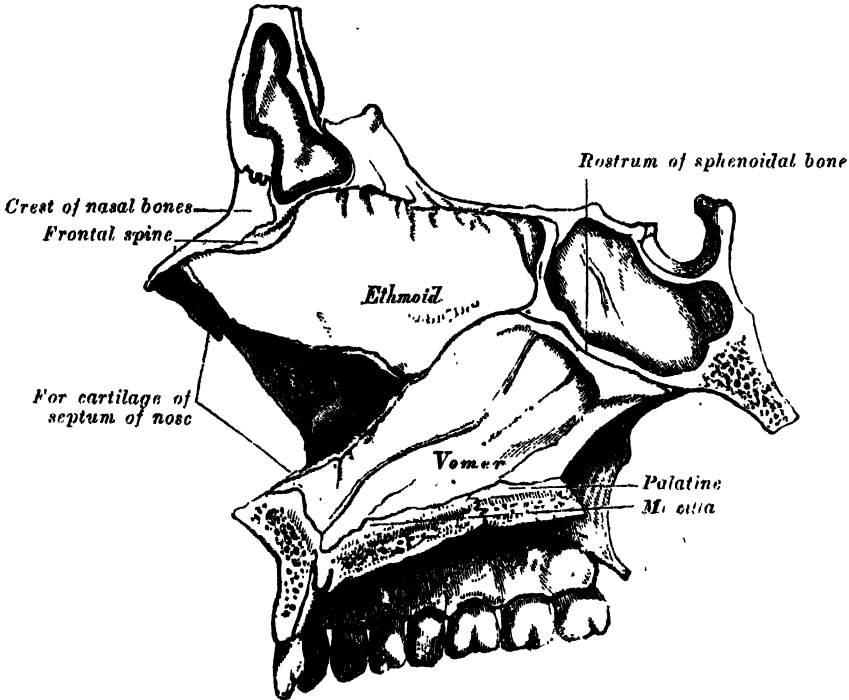
THE VOMER

The *vomer* is thin, somewhat quadrilateral in shape, and forms the hinder and lower part of the nasal septum (fig. 319); it has two surfaces and four borders. The *surfaces* (fig. 320) are marked by small furrows for blood-vessels, and on each is the *nasopalatine groove* which runs obliquely downwards and forwards, and lodges the *nasopalatine nerve* and vessels. The *superior border*, the thickest, presents a deep furrow, bounded on either side by a horizontal projecting ala; the furrow receives the rostrum of the sphenoidal bone, and the alae articulate with the sphenoidal conchæ, the sphenoidal processes of the palatine bones and the vaginal processes of the medial pterygoid laminae of the sphenoidal bone. The *inferior border* articulates with the nasal crest formed by the maxillæ and palatine bones. The *anterior border* is the longest; its upper half articulates with the *lamina perpendicularis* of the ethmoidal bone, its lower is grooved for the reception of the inferior margin of the cartilage of the septum of the nose. The *posterior border* is free, concave, and separates the choanæ or posterior nasal apertures; it is thick and bifid above, thin below. The anterior end of the vomer articulates with the posterior margin of the incisor crest of the maxillæ and projects downwards between the incisive canals.

Ossification.—At an early period the septum of the nose consists of a plate of cartilage. The superior part of this cartilage is ossified to form the *lamina perpendicularis* of the ethmoid; its antero-inferior portion persists as the cartilage of the septum, whilst the vomer is ossified in the membrane covering its postero-inferior part. About the eighth week of foetal life two ossific centres, one on either side of the middle line, appear in this part of the membrane, medial to and a little behind the paraseptal cartilages. About the third month these centres unite below,

and thus a deep groove is formed (fig. 321) in which the cartilage of the septum is lodged. As growth proceeds, the union of the bony lamellæ extends upwards and forwards, and at the same time the intervening plate of cartilage undergoes

FIG. 319.—Median wall of left nasal cavity, showing vomer *in situ*.



absorption. By the age of puberty the lamellæ are almost completely united, but evidence of the bilaminar origin of the bone is seen in the everted alæ of its upper border and the groove on its anterior border. Up to a certain stage the vomer is entirely derived from membrane, but 'it becomes added to by the ossification of the hinder end of the anterior paraseptal cartilage.* From this part of the

FIG. 320.—The vomer.

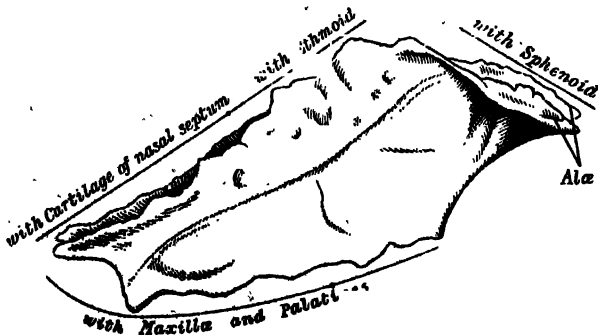


FIG. 321.—Vomer of infant.



ossified anterior paraseptal cartilage a plate of bone descends by the side of the primary part of the vomer, and fuses with it. The vomeronasal cartilage of Jacobson is the persistent anterior paraseptal cartilage.*

* Fawcett, *Journal of Anatomy and Physiology*, vol. xlv.

SUTURAL BONES (OSSA SUTURARUM)

In addition to the usual centres of ossification of the cranial bones, others may occur in the course of the sutures, giving rise to irregular, isolated, *sutural* or *Wormian** bones. They occur most frequently in the course of the lambdoidal suture, but are occasionally seen at the fonticuli, especially the posterior. One, the *pterion ossicle*, sometimes exists between the sphenoidal angle of the parietal and the great wing of the sphenoid. They have a tendency to be more or less symmetrical on the two sides of the skull, and vary much in size. Their number is generally limited to two or three; but more than a hundred have been found in the skull of a hydrocephalic subject.

Applied Anatomy.—An arrest in the ossifying process may give rise to deficiencies, gaps, or fissures in the cranium, which are of importance from a medico-legal point of view, as they are liable to be mistaken for fractures. The fissures generally extend from the margins towards the centre of a bone, but the gaps may be found in the middle as well as at the edges. In course of time they may become filled with thin laminae of bone. In many of these cases, however, the gaps must be regarded as due to absorption of bone already formed rather than as congenital deficiencies; this is especially the case when they appear in the centre of a bone such as the parietal, the ossification of which has already been described as occurring in a regular manner radiating from two centres. The condition is most commonly seen in very badly nourished children affected with congenital syphilis, and is called *craniotabes*.

FACIAL BONES (OSSA FACIEI)

THE MAXILLÆ

The maxillæ are the largest bones of the face, excepting the mandible, and form, by their union, the whole of the upper jaw. Each assists in completing the roof of the mouth, the floor and lateral wall of the nose, and the floor of the orbit; they also enter into the formation of the infratemporal and pterygo-palatine fossæ, and the inferior orbital and pterygomaxillary fissures.

Each bone consists of a body and four processes—zygomatic, frontal, alveolar, and palatine.

The body is somewhat pyramidal in shape. It has four surfaces,—anterior, infratemporal, orbit. and nasal—and these enclose a large cavity, the maxillary sinus or antrum of Highmore.

The *anterior surface* (fig. 322) is directed forwards and lateralwards. On its lower part is a series of eminences (*juga alveolaria*) corresponding to the positions of the roots of the teeth. Just above those of the incisor teeth is a depression, the *incisive fossa*, which gives origin to the *Depressor septi*; to the alveolar border below the fossa a slip of the *Orbicularis oris* is attached; above and a little lateral to it, the *Nasalis* arises. Lateral to the incisive fossa is a larger and deeper depression, the *canine fossa*; it is separated from the incisive fossa by the *canine eminence*, which corresponds to the socket of the canine tooth; the fossa gives origin to the *Caninus*. Above the canine fossa is the *infraorbital foramen*, the end of the infraorbital canal; it transmits the infraorbital vessels and nerve. Above the foramen is the margin of the orbit, which gives origin to the orbital head of the *Quadratus labii superioris*. Medially, the anterior surface is limited by a deep concavity, the *nasal notch*; the margin of the notch gives attachment to the *Dilatator naris posterior* and ends below in a pointed process, which with its fellow of the opposite side forms the *anterior nasal spine*.

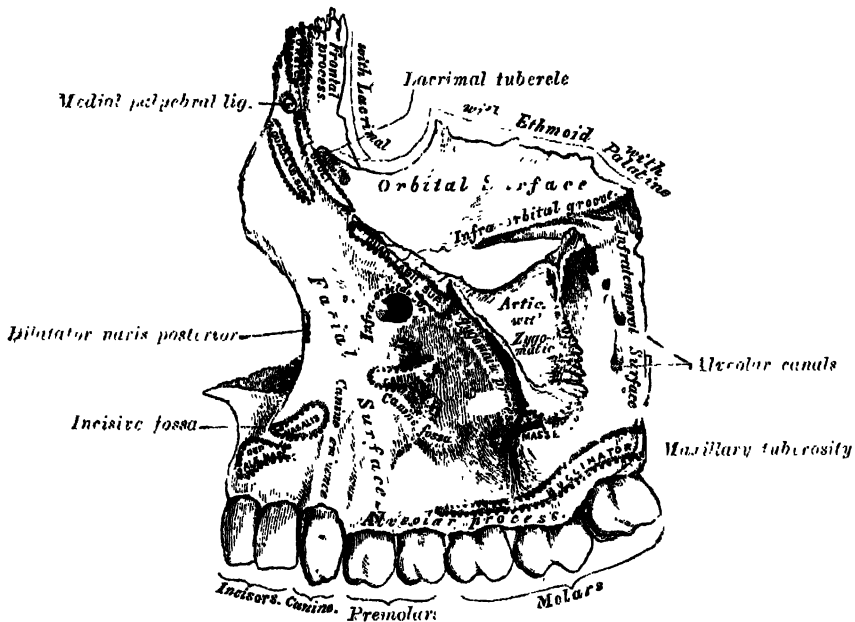
The *infratemporal surface* (fig. 322) is convex, directed backwards and lateralwards, and forms part of the infratemporal fossa. It is separated from the anterior surface by the zygomatic process and by a ridge which extends upwards from the socket of the first molar tooth. It is pierced near its centre by the apertures of two or three *alveolar canals*, which transmit the posterior superior alveolar vessels and nerves. At the lower part of this surface is a rounded eminence, the *maxillary tuberosity*, which is rough for articulation with the pyramidal process of the palatine bone; it gives origin to a few

* Old Worm, Professor of Anatomy at Copenhagen 1624-1639, was erroneously supposed to have given the first detailed description of these bones.

fibres of the *Pterygoideus internus*, and in some cases articulates with the lateral pterygoid lamina of the sphenoidal bone. Immediately above this is a smooth surface, which forms the anterior boundary of the pterygopalatine fossa, and is grooved for the maxillary nerve; this groove is directed lateralwards and slightly upwards, and is continuous with the infraorbital groove on the orbital surface.

The *orbital surface* (fig. 322) is smooth and triangular, and forms the greater part of the floor of the orbit. Its *medial border* presents anteriorly a notch, the *lacrimal notch*, behind which it articulates from before backwards with the lacrimal bone, the lamina papyracea of the ethmoidal bone, and the orbital process of the palatine bone. Its *posterior border* is smooth and rounded; it forms the anterior margin of the inferior orbital fissure, and its central part

FIG. 322.—Left maxilla. Outer surface.



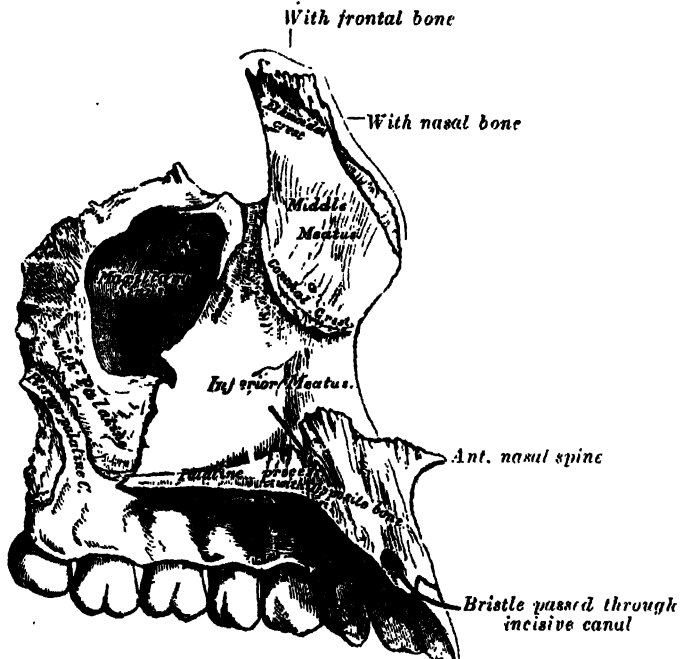
is notched by the commencement of the infraorbital groove. The *anterior border* forms a small part of the circumference of the base of the orbit, and is continuous medially with the frontal process, and laterally with the zygomatic process. The *infraorbital groove*, for the passage of the infraorbital vessels and nerve, begins at the middle of the posterior border, where it is continuous with the groove near the upper edge of the infratemporal surface; it passes forwards and ends in the *infraorbital canal*, which opens just below the margin of the orbit. At the medial and front part of the orbital surface, just lateral to the lacrimal groove, is a depression, which gives origin to the *Obliquus oculi inferior*.

The *nasal surface* (fig. 323) presents in its upper and posterior part a large, irregular opening leading into the maxillary sinus. At the upper border of this aperture are some broken air-cells, which, in the articulated skull, are closed by the ethmoidal and lacrimal bones. Below it is a smooth concavity which forms part of the inferior meatus of the nasal cavity, and behind it is a rough surface for articulation with the vertical part of the palatine bone; this surface is traversed by a groove, which begins near the middle of the posterior border, runs obliquely downwards and forwards, and is converted into the *pterygo-palatine canal* by the vertical part of the palatine bone and the pterygoid process of the sphenoidal bone. In front of the opening of the maxillary sinus is a deep groove, the *sulcus lacrimalis*, which is converted into the *nasolacrimal canal* by the lacrimal bone and inferior nasal concha; this canal opens into the inferior meatus of the nose and transmits the *nasolacrimal duct*. More

anteriorly is an oblique ridge, the *crista conchalis*, for articulation with the inferior nasal concha. The shallow concavity below this ridge forms part of the inferior meatus of the nose, and that above it part of the atrium of the middle meatus.

The **maxillary sinus** or **antrum of Highmore** is a large pyramidal cavity within the body of the maxilla: its *apex*, directed laterally, is formed by the zygomatic process; its *base*, directed medially, by the lateral wall of the nose. Its walls are thin, and correspond to the nasal, orbital, anterior, and infratemporal surfaces of the body of the bone. Its base, or nasal wall, presents, in the disarticulated bone, a large, irregular aperture communicating with the nasal cavity. In the articulated skull this aperture is much reduced in size by the following bones: the uncinat process of the ethmoidal above, the

FIG. 323.—Left maxilla. Nasal surface.



maxillary process of the inferior nasal concha below, the vertical part of the palatine behind, and a small part of the lacrimal above and in front (fig. 324). The sinus communicates with the middle meatus of the nose, generally by two small apertures, one of which is usually closed, in the recent state, by mucous membrane. On the *posterior wall* are the *alveolar canals*, transmitting the posterior superior alveolar vessels and nerves to the molar teeth. The *floor* is formed by the alveolar process of the maxilla, and its lowest part is usually about 1.25 cm. below the level of the floor of the nasal cavity. In a large proportion of cases radiating septa of varying sizes spring from the floor of the sinus in the intervals between adjacent teeth; in some cases the floor is perforated by the fangs of the molar teeth.* The infraorbital canal usually projects into the sinus as a well-marked ridge extending from the roof to the anterior wall; ridges, caused by the alveolar canals, are sometimes seen in the posterior wall. The size of the cavity varies in different skulls, and even on the two sides of the same skull.†

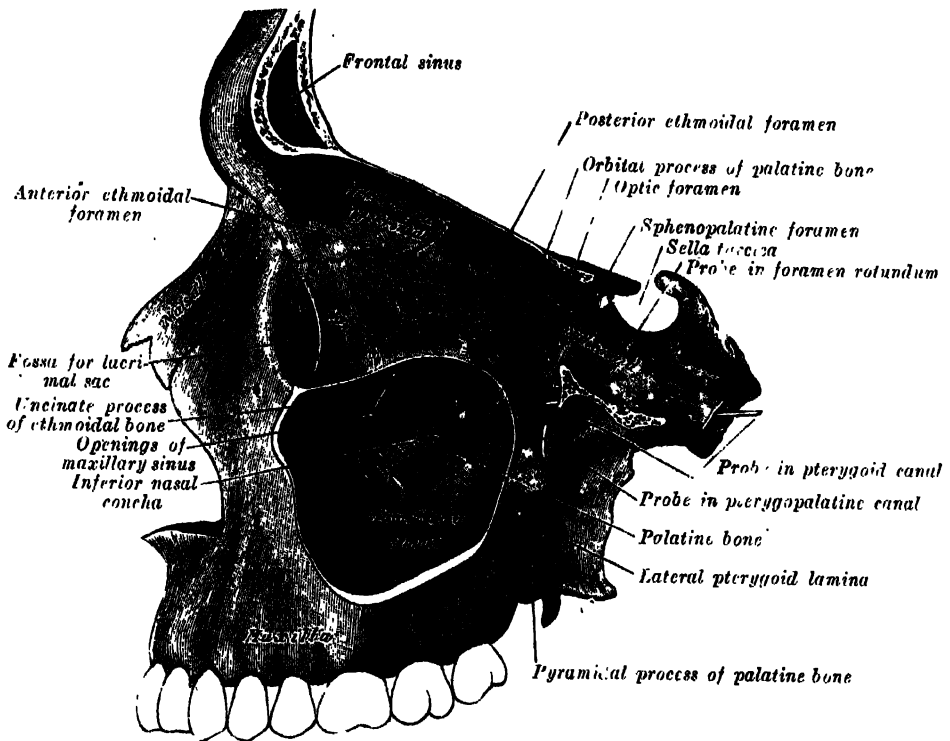
* The number of teeth whose roots are in relation with the floor of the antrum is variable. The sinus may extend so as to be in relation to all the teeth of the true maxilla, from the canine to the third molar.—(Salter.)

† Logan Turner (*op. cit.*) gives the following measurements as those of an average-sized sinus: vertical height opposite first molar tooth, 3.5 cm.; transverse breadth, 2.5 cm.; and anteroposterior depth, 3.2 cm.

Applied Anatomy.—The extreme thinness of the walls of this cavity affords an explanation of the fact that a tumour growing from the maxillary sinus and encroaching upon the adjacent parts may push up the floor of the orbit, and displace the eyeball; may project into the nose; may protrude forwards on to the cheek; or may make its way backwards into the infratemporal fossa, or downwards into the mouth.

The **zygomatic process** is a rough triangular eminence, situated at the angle of separation of the anterior, infratemporal, and orbital surfaces. *In front* it forms part of the anterior surface of the body of the bone; *behind*, it is concave, and continuous with the infratemporal surface; *above*, it is rough and serrated for articulation with the zygomatic bone; *below*, it presents the prominent arched border which marks the division between the anterior and infratemporal surfaces.

FIG. 324.—Left maxillary sinus opened from the exterior.

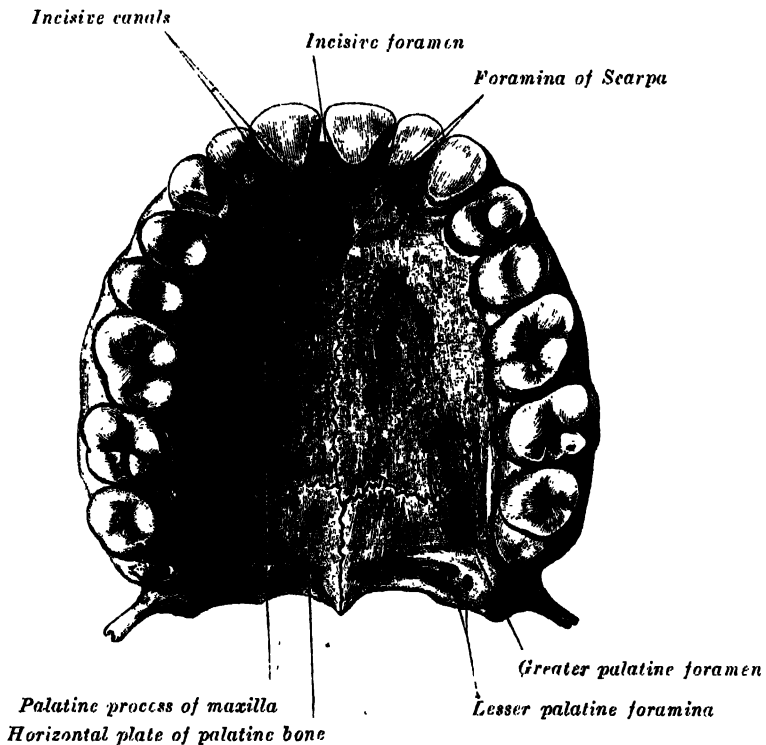


The **frontal process** projects upwards and backwards between the nasal and lacrimal bones. Its *lateral surface* is smooth, continuous below with the anterior surface of the body, and gives attachment to the angular head of the *Quadratus labii superioris*, the *Orbicularis oculi*, and the *medial palpebral ligament*. Its *medial surface* forms part of the lateral wall of the nasal cavity; a rough, uneven area, at its upper part, articulates with the ethmoidal bone and closes in the anterior ethmoidal cells; below this is an oblique ridge, the *crista ethmoidalis*, the posterior end of which articulates with the middle nasal concha, while the anterior part is termed the *agger nasi*; the *crista ethmoidalis* forms the upper limit of the atrium of the middle meatus. The *upper extremity* articulates with the frontal bone, and the *anterior border* with the nasal bone; the *posterior border* is thick, and hollowed into a groove, which is continuous below with the sulcus lacimalis on the nasal surface of the body and posteriorly, in the articulated skull, with the lacrimal groove on the lacrimal bone, the two grooves forming the *lacrimal fossa* for the lodgment of the lacrimal sac. The lateral margin of the groove is named the *anterior lacrimal crest*, and is continuous below with the orbital margin; at its junction with the orbital surface

is a small tubercle, the *lacrimal tubercle*, which serves, in the living subject, as a guide to the position of the lacrimal sac.

The **alveolar process**, thick and arched, is broader behind than in front, and excavated into cavities or alveoli for the reception of the roots of the teeth. These cavities are eight in number, and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and are subdivided into three minor cavities by septa; those for the incisors are single, but deep and narrow. The *Buccinator* arises from the outer surface of this process, as far forward as the first molar tooth. When the maxillæ are articulated with each other, their alveolar processes together form the *alveolar arch*.

FIG. 325.—The bony palate and alveolar arch.



The **palatine process**, thick and strong, is horizontal and projects medially from the nasal surface of the bone. It forms a considerable part of the floor of the nose and the roof of the mouth, and is much thicker in front than behind. Its *inferior surface* (fig. 325), concave, rough and uneven, forms, with the palatine process of the opposite bone, the anterior three-fourths of the hard palate. It is perforated by numerous foramina for the passage of the nutrient vessels, and presents depressions for the lodgment of the palatine glands; it is channelled at the posterior part of its lateral border by two grooves, for the transmission of the descending palatine vessels, and the anterior palatine nerve. When the two maxillæ are articulated, a funnel-shaped opening, the *incisive foramen*, is seen in the middle line, immediately behind the incisor teeth. In this opening the orifices of two lateral canals are visible; they are named the *incisive canals* or *foramina of Stensen*; each leads upwards into the corresponding nasal cavity and transmits the terminal branch of the greater palatine artery and the nasopalatine nerve. Occasionally there are two additional apertures in the middle line; they are termed the *foramina of Scarpa*, and when present transmit the nasopalatine nerves, the left passing through the anterior, and the right through the posterior foramen. On the under surface

of the palatine process, a delicate suture, well seen in young skulls, may sometimes be noticed extending lateralwards and forwards from the incisive foramen to the interval between the lateral incisor and the canine teeth. The small part in front of this suture constitutes the *premaxilla*, or *os incisivum*, which in most vertebrates forms an independent bone; it includes the whole thickness of the alveolus, the corresponding part of the floor of the nose and the anterior nasal spine, and contains the sockets of the incisor teeth. The *upper surface* of the palatine process is concave from side to side, smooth, and forms the greater part of the floor of the nasal cavity; close to its medial margin is the upper orifice of the incisive canal. The *lateral border* of the process is fused with the rest of the bone. The *medial border*, thicker in front than behind, is

FIG. 326.—Anterior surface of maxilla at birth.

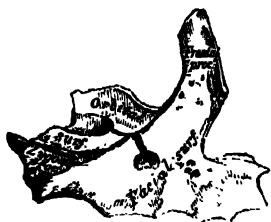
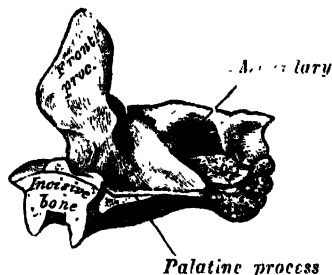


FIG. 327.—Inferior surface of maxilla at birth.



FIG. 328.—Nasal surface of maxilla at birth.



raised into a ridge, the *nasal crest*, which, with the corresponding ridge of the opposite bone, forms a groove for the reception of the vomer. The front part of this ridge rises to a considerable height, and is named the *incisor crest*; it is prolonged forwards into a sharp process, which, together with the similar process of the opposite bone, forms the *anterior nasal spine*. The *posterior border* is serrated for articulation with the horizontal part of the palatine bone.

Ossification.—The maxilla is mainly developed in membrane. Mall* and Fawcett† have shown that it is ossified from two centres, one for the maxilla proper and one for the premaxilla. These centres appear at the end of the sixth week of foetal life, that for the maxilla proper commencing above the canine tooth-germ; they unite at the end of the second or early in the third month, but the suture between them (fig. 327) persists on the palate until nearly middle life; the frontal process of the bone is developed from both centres. The ossifying maxilla invades and incorporates the paranasal process of the cartilaginous nasal capsule, and this may account for the small islands of cartilage which are sometimes found in the ossifying maxilla. The maxillary sinus appears as a shallow groove (fig. 328) on the nasal surface of the bone about the fourth month of foetal life, but does not reach its full size until after the second dentition. The infraorbital vessels and nerve

* *American Journal of Anatomy*, vol. v. 1906.

† *Journal of Anatomy and Physiology*, vol. xlv. 1911.

lie for a time in an open groove, the anterior part of which is converted into the infraorbital canal by a lamina of bone which grows from the lateral side of the groove.

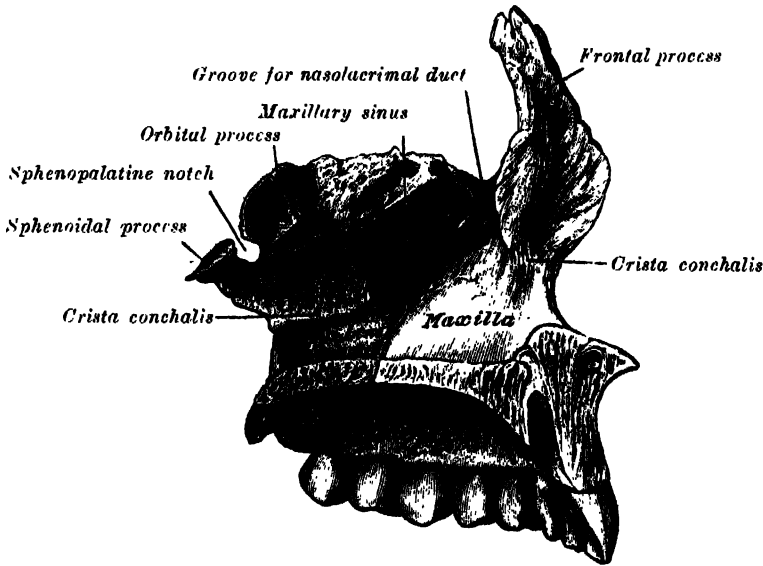
CHANGES PRODUCED IN THE MAXILLA BY AGE.

At birth the transverse and anteroposterior diameters of the bone are each greater than the vertical. The frontal process is well-marked and the body of the bone consists of little more than the alveolar process, the tooth-sockets reaching almost to the floor of the orbit. The maxillary sinus appears as a furrow on the lateral wall of the nose. In the adult the vertical diameter is the greatest, owing to the development of the alveolar process and the increase in size of the sinus. In old age, the bone reverts in some measure to the infantile condition: its height is diminished, and after the loss of the teeth the alveolar process is absorbed, and the lower part of the bone contracted and reduced in thickness.

THE PALATINE BONES (OSSA PALATINA)

The palatine bones are situated at the posterior part of the nasal cavity between the maxillæ and the pterygoid processes of the sphenoidal bone (fig. 329). Each assists in forming the floor and lateral wall of the nasal cavity, the roof of the mouth, and the floor of the orbit; it enters into the formation of the

FIG. 329.—Articulation of left palatine bone and left maxilla.

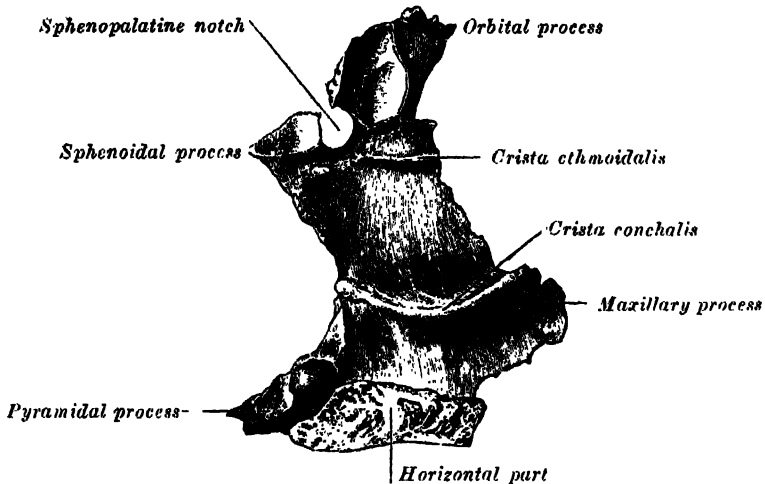


pterygopalatine and pterygoid fossæ, and the inferior orbital fissure. It somewhat resembles the letter L, and consists of a horizontal and a vertical part, and three outstanding processes—viz. the pyramidal process, which is directed backwards, lateralwards, and downwards, from the junction of the two parts, and the orbital and sphenoidal processes, which surmount the vertical part, and are separated by a deep notch, the sphenopalatine notch.

The horizontal part (figs. 330, 331) is quadrilateral, and has two surfaces and four borders. The *nasal surface*, concave from side to side, forms the posterior part of the floor of the nasal cavity. The *palatine surface* forms, with the corresponding surface of the opposite bone, the posterior fourth of the hard palate; near its posterior margin is a curved ridge. The *posterior border* is thin and concave; to it and to the palatine surface as far forwards as the curved ridge just described the expanded tendon of the Tensor veli palatini is attached. Its medial end is thin and pointed, and, when united with that of the opposite bone, forms a projecting process, the *posterior nasal*

spine, for the attachment of the Musculus uvula. The anterior border is serrated, and articulates with the palatine process of the maxilla. The lateral border is united with the lower margin of the vertical part, and is grooved by the lower

FIG. 330.—Left palatine bone. Nasal aspect. (Enlarged.)



end of the pterygopalatine canal. The medial border, thick and serrated, articulates with the corresponding border of the opposite bone, and forms with it a crest which articulates with the posterior part of the lower edge of the vomer, and is continuous anteriorly with the nasal crest of the maxillæ.

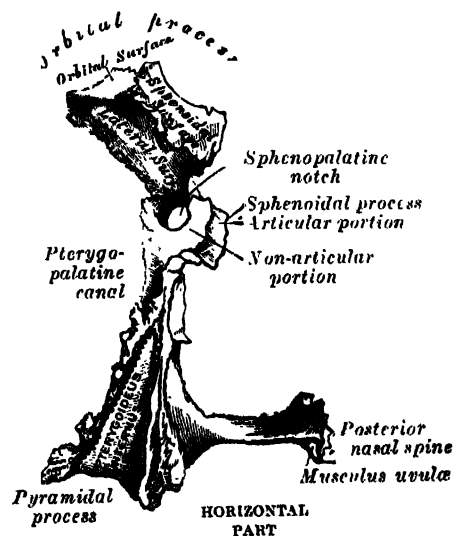
The vertical part (figs. 330, 331), thin and of an oblong form, has two surfaces and four borders.

The nasal surface exhibits at its lower part a broad, shallow depression which forms part of the inferior meatus of the nasal cavity. Immediately above this is a horizontal ridge, the crista conchalis, for articulation with the inferior nasal concha; still higher is a second broad, shallow depression, which forms part of the middle meatus, and is limited above by the crista ethmoidalis, for articulation with the middle nasal concha. Above the crista ethmoidalis is a narrow, horizontal groove, which forms part of the superior meatus.

The maxillary surface is rough and irregular throughout the greater part of its extent, for articulation with the nasal surface of the maxilla; its upper and posterior part is smooth and forms the medial wall of the pterygopalatine fossa; its front portion is also smooth and forms the posterior part of the medial wall of the maxillary sinus.

On the posterior part of the maxillary surface is a deep vertical groove, the pterygopalatine sulcus, which in the articulated skull is converted into the pterygopalatine canal by the maxilla and the pterygoid process of the sphenoidal bone; this canal transmits the descending palatine vessels, and the palatine nerves.

FIG. 331.—Left palatine bone. Posterior aspect. (Enlarged.)



The *anterior border* is thin and irregular ; at the level of the *crista conchalis* is a pointed, projecting lamina, the *maxillary process*, which is directed forwards below and behind the maxillary process of the inferior nasal concha with which it articulates, and assists in forming the medial wall of the maxillary sinus. The *posterior border* (fig. 331) presents a deep groove, the edges of which are serrated for articulation with the medial pterygoid lamina of the sphenoidal bone. This border is continuous above with the sphenoidal process ; below, it expands into the pyramidal process. The *superior border* supports the orbital process in front and the sphenoidal process behind. These processes are separated by the *sphenopalatine notch*, which is converted into the *sphenopalatine foramen* by the under surface of the body of the sphenoidal bone. In the articulated skull this foramen leads from the pterygopalatine fossa into the posterior part of the superior meatus of the nose, and transmits the sphenopalatine vessels and the posterior superior nasal nerves. The *inferior border* is fused with the lateral edge of the horizontal part, and in front of the pyramidal process is grooved by the lower end of the pterygopalatine canal.

The *pyramidal process* (tuberosity) projects backwards, lateralwards, and downwards from the junction of the horizontal and vertical parts of the bone, and fits into the angular interval between the lower ends of the pterygoid laminae. On its *posterior surface* is a smooth, grooved, triangular area, limited on either side by a rough articular furrow. The furrows articulate with the pterygoid laminae, while the grooved triangular area completes the lower part of the pterygoid fossa and gives origin to a few fibres of the *Pterygoideus internus*. The anterior part of the *lateral surface* is rough for articulation with the maxillary tuberosity ; its posterior part consists of a smooth triangular area which appears, in the articulated skull, at the lower part of the infratemporal fossa between the maxillary tuberosity and the lateral pterygoid lamina. In the *base* of the pyramidal process, close to its union with the horizontal part, are the lesser palatine foramina for the transmission of the middle and posterior palatine nerves.

The *orbital process* is directed upwards and lateralwards from the front of the vertical part, to which it is joined by a constricted neck. It encloses an air-cell, and presents *five surfaces*, of which three are articular and two non-articular. The articular surfaces are : (1) the *anterior* or *maxillary*, of an oblong form, is directed forwards, lateralwards, and downwards, and articulates with the maxilla ; (2) the *posterior* or *sphenoidal*, directed backwards, upwards, and medialwards, presents the opening of the air-cell, which usually communicates with the sphenoidal sinus ; the margins of the opening articulate with the sphenoidal concha ; (3) the *medial* or *ethmoidal*, directed medialwards and forwards, articulates with the labyrinth of the ethmoidal bone. In some cases, the air-cell opens on this surface and then communicates with the posterior ethmoidal cells ; more rarely it opens on the ethmoidal and sphenoidal surfaces, and then communicates with the posterior ethmoidal cells and the sphenoidal sinus. The non-articular surfaces are : (1) the *superior* or *orbital*, triangular in shape, is directed upwards and lateralwards, and forms the posterior part of the floor of the orbit ; and (2) the *lateral*, of an oblong form, is directed towards the pterygopalatine fossa, and is separated from the orbital surface by a rounded border, which enters into the formation of the medial part of the inferior orbital fissure ; on this surface is a *transverse groove* which lodges the maxillary nerve and is continuous with the groove on the upper part of the infratemporal surface of the maxilla.

The *sphenoidal process* is a thin, compressed plate, smaller and on a lower level than the orbital process ; it is directed upwards and medialwards. Its *superior surface* articulates with the under surface of the sphenoidal concha and the root of the medial pterygoid lamina ; it presents a *groove* which contributes to the formation of the pharyngeal canal. The *inferomedial surface* is concave, and forms a small part of the roof and lateral wall of the nasal cavity. The posterior part of the *lateral surface* articulates with the medial pterygoid lamina ; the anterior part is smooth, and forms a portion of the medial wall of the pterygopalatine fossa. The *posterior border* is rough and articulates with the vaginal process of the medial pterygoid lamina. The *anterior border* forms the posterior boundary of the sphenopalatine notch. The *medial border* articulates with the ala of the vomer.

The orbital and sphenoidal processes are separated from one another by the *sphenopalatine notch* which is converted into the sphenopalatine foramen by the under surface of the body of the sphenoidal bone ; sometimes the two processes are united by a spicule of bone which then completes the upper boundary of the foramen.

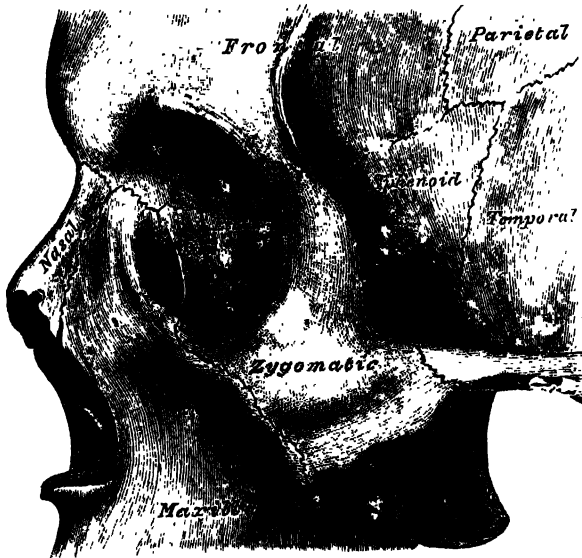
Ossification.—The palatine bone is ossified in membrane from a single centre, which makes its appearance in the eighth week of foetal life in the vertical part at the side of the nasal cavity. From this point ossification spreads upwards into the orbital and sphenoidal processes, medialwards into the horizontal part, and downwards into the pyramidal process.

At the time of birth the height of the vertical part is about equal to the transverse width of the horizontal part, whereas in the adult it measures nearly twice as much.

THE ZYGOMATIC BONES (OSSA ZYGOMATICA)

The **zygomatic** or **malar** bones are situated at the upper and lateral parts of the face. Each forms the prominence of the cheek, part of the lateral wall and floor of the orbit, and parts of the temporal and infratemporal fossæ

FIG. 332.—Left zygomatic bone *in situ*.



(fig. 332) ; it is quadrangular in shape and has two surfaces, four borders, and four processes.

The *malar surface* (figs. 332, 333) is convex and is perforated near its orbital border by the *zygomaticofacial foramen* for the passage of the *zygomaticofacial nerve and vessels* ; below this foramen is a slight elevation, which gives origin to the *Zygomaticus*. The *temporal surface* (fig. 334), directed downwards and medialwards, is concave, presenting anteriorly a rough, triangular area, for articulation with the maxilla, and posteriorly a smooth, concave surface, the upper part of which forms the anterior boundary of the temporal fossa, the lower, a part of the infratemporal fossa. Near the middle of this surface is the *zygomaticotemporal foramen* for the transmission of the *zygomaticotemporal nerve*.

The *anterosuperior* or *orbital border* is smooth, concave, and forms a considerable part of the circumference of the base of the orbit. The *anteroinferior* or *maxillary border* is rough, and articulates with the maxilla ; near the orbital margin it gives origin to the zygomatic head of the *Quadratus labii superioris*. The *posterosuperior* or *temporal border*, curved like an italic letter *f*, is continuous above with the commencement of the temporal line, and below with

the upper border of the zygomatic arch; the temporal fascia is attached to it. The posteroinferior or zygomatic border affords attachment by its rough edge to the Masseter.

The frontosphenoidal process is thick and serrated, and articulates with the zygomatic process of the frontal bone. On its orbital surface, just within the orbital margin and about 11 mm. below the zygomaticofrontal suture is a tubercle of varying size and form, but present in 95 per cent. of skulls (Whitnall *). The orbital process is a thick, strong plate, projecting backwards and medialwards from the orbital margin. Its orbital surface forms, by its junction with the orbital surface of the maxilla and with the great wing of the sphenoidal bone, part of the floor and lateral wall of the orbit. On it are usually seen the orifices of two canals, the zygomatico-orbital foramina; one of these canals opens into the temporal fossa, the other on the malar surface of the bone; the former transmits the zygomaticotemporal, the latter the zygomaticofacial nerve. Its temporal surface, smooth and convex, forms parts of

FIG. 333.—Left zygomatic bone.
Malar surface.

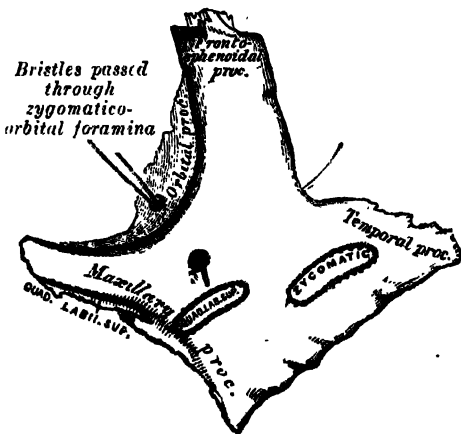
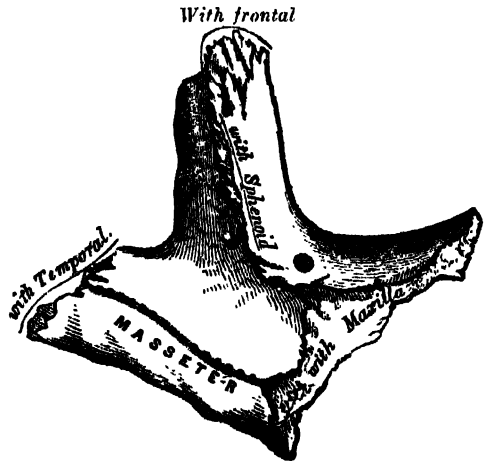


FIG. 334.—Left zygomatic bone.
Temporal surface.



the temporal and infratemporal fossæ. Its anterior margin, smooth and rounded, is part of the circumference of the base of the orbit. Its superior margin, rough, and directed horizontally, articulates with the frontal bone behind the zygomatic process. Its posterior margin is serrated for articulation with the great wing of the sphenoidal bone and the orbital surface of the maxilla. At the angle of junction of the sphenoidal and maxillary portions, a short, concave, non-articular part is generally seen; this forms the anterior boundary of the inferior orbital fissure; this non-articular part is sometimes absent, and the fissure is then completed by the junction of the maxilla and the sphenoidal bone, or by the interposition of a small sutural bone in the angular interval between them. The infraorbital process is pointed and articulates with the maxilla, just above the infraorbital foramen. The temporal process is directed backwards and ends in an oblique serrated margin which articulates with the zygomatic process of the temporal.

Ossification.—The zygomatic bone is ossified from one centre which appears about the eighth week of foetal life below the zygomatic (temporomalar) nerve. The bone is sometimes divided by a horizontal suture into an upper larger, and a lower smaller division. In some quadrumana the zygomatic bone consists of two parts, an orbital and a malar.

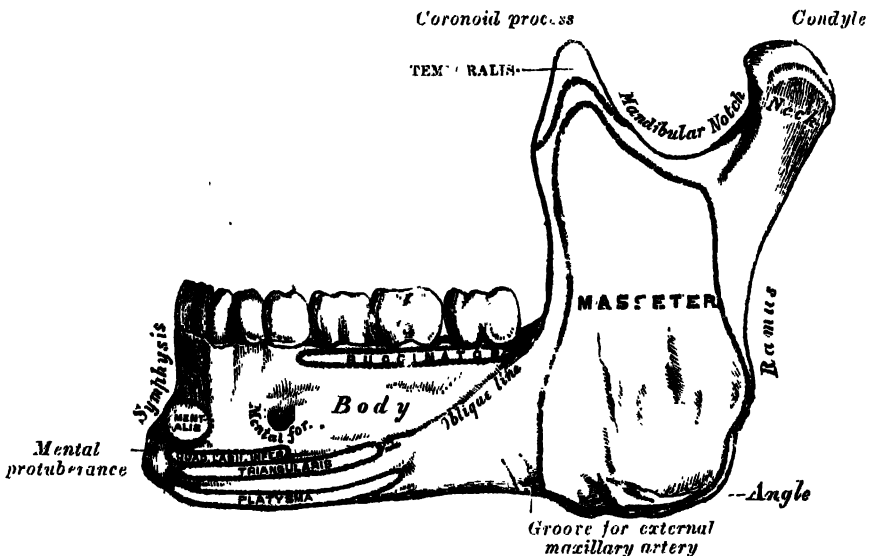
* *Journal of Anatomy and Physiology*, vol. xiv.—The structures attached to this tubercle are: (1) the check ligament of the Rectus lateralis; (2) the lateral end of the aponeurosis of the Levator palpebræ superioris; (3) the suspensory ligament of the eye (Lockwood); and (4) the lateral extremities of the superior and inferior tarsi.

THE MANDIBLE (MANDIBULA)

The **mandible**, the largest and strongest bone of the face, consists of a curved, horizontal portion, the *body*, from the ends of which two perpendicular portions, the *rami*, project upwards.

The *body* is curved somewhat like a horseshoe, and has two surfaces and two borders. The *external surface* (fig. 335) is marked in the upper part of the median line by a faint ridge, indicating the *symphysis* or junction of the two pieces of which the bone is composed at an early period of life. This ridge divides below and encloses a triangular eminence, the *mental protuberance*, the base of which is depressed in the centre but raised on either side to form the *mental tubercle*. On either side of the ridge, just below the incisor teeth, is the *incisive fossa*, which gives origin to the *Mentalis* and to a small portion of the *Orbicularis oris*. Below the second premolar tooth, on either side, midway

FIG. 335.—Mandible. External surface. Side view.



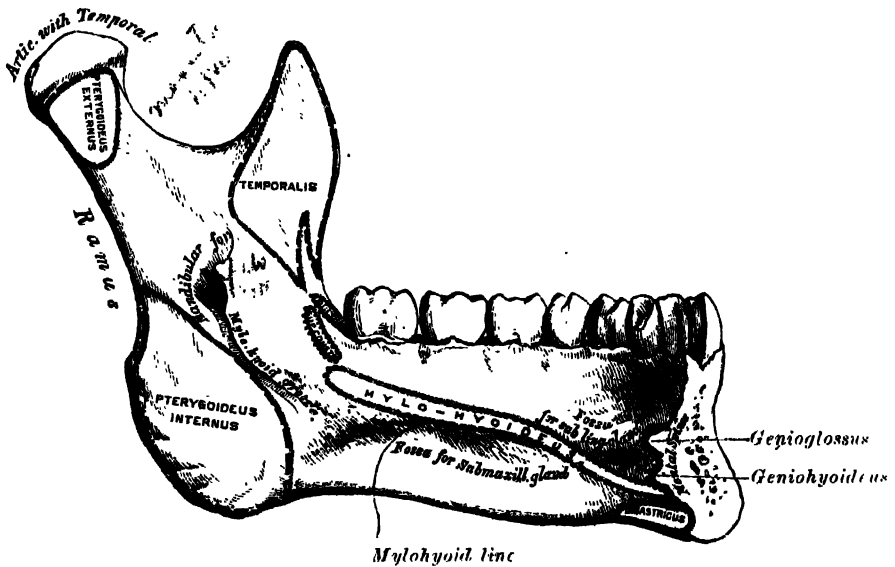
between the upper and lower borders of the body, is the *mental foramen*, for the exit of the mental vessels and nerve. Running backwards and upwards from each mental tubercle is a faint ridge, the *oblique line*, which is continuous with the anterior border of the ramus; it affords attachment to the *Quadratus labii inferioris* and *Triangularis*; the *Platysma* is attached below it.

The *internal surface* (fig. 336) is concave from side to side. Near the lower part of the symphysis is a pair of laterally placed spines, termed the *mental spines*, which give origin to the *Genioglossi*. Immediately below these is a second pair of spines, or more frequently a median ridge or impression for the origins of the *Geniohyoidei*. In some cases the mental spines are fused to form a single eminence; in others they are absent, and their position is indicated merely by an irregularity of the surface. Above the mental spines a median foramen and furrow are sometimes present; they mark the line of union of the halves of the bone. Below the mental spines, on either side of the middle line, is an oval depression, the *digastric fossa*, for the attachment of the anterior belly of the *Digastricus*. Extending upwards and backwards on either side from the lower part of the symphysis to a point behind the last molar tooth is the *mylohyoid line* which gives origin to the *Mylohyoideus*; the posterior part of this line, near the alveolar margin, gives attachment to a small part of the *Constrictor pharyngis superior*, and to the *pterygomandibular raphe*. Above the anterior part of this line is a smooth triangular area against which the *sublingual gland* rests, and below the posterior part, an oval fossa for the *submaxillary gland*.

The *alveolar part* or upper portion of the body is hollowed into sixteen cavities or alveoli, for the reception of the teeth; these cavities vary in depth and size, and are single or subdivided by septa, according to the teeth which they contain. From the lateral surface of the alveolar part, on either side, the Buccinator takes origin as far forwards as the first molar tooth. The *inferior border* or *base* of the mandible is rounded, and is thicker in front than behind: at the point where it joins the lower border of the ramus a shallow groove, for the external maxillary artery, may be present.

The *ramus* is quadrilateral in shape, and has two surfaces, four borders, and two processes. The *lateral surface* (fig. 335) is flat and marked by oblique ridges at its lower part; it gives attachment throughout nearly the whole of its extent to the Masseter. The *medial surface* (fig. 336) presents about its centre the *mandibular foramen*, which transmits the inferior alveolar vessels and nerve. The foramen is overlapped in front by a triangular process, the *lingula mandibule*, to the margins of which the sphenomandibular ligament

FIG. 336.—Mandible. Internal surface. Side view.



is attached; behind the lingula is a notch from which the *mylohyoid groove* or *sulcus* runs obliquely downwards and forwards, and lodges the mylohyoid vessels and nerve. Behind this groove is a rough surface, for the insertion of the Pterygoideus internus. Into the anterosuperior part of the medial surface a part of the Temporalis is inserted. The *mandibular canal* runs from the mandibular foramen obliquely downwards and forwards in the ramus, and then horizontally forwards in the body, where it is placed under the alveoli and communicates with them by small openings. It contains the inferior alveolar vessels and nerve, from which branches enter the roots of the teeth. Between the roots of the first and second premolar teeth the mandibular canal divides into the *mental* and *incisive canals*; the mental canal runs upwards, backwards and lateralwards and ends at the mental foramen; the incisive canal is continued forward below the incisor teeth. The *lower border* of the ramus is thick, straight, and continuous with the inferior border of the body of the bone. At its junction with the posterior border is the *angle* of the mandible, which may be either inverted or everted, and is marked by rough, oblique ridges on each side, for the insertion of the Masseter laterally, and the Pterygoideus internus medially; the stylomandibular ligament is attached to the angle, between these muscles. The *anterior border* is thin above, thicker below, and continuous with the oblique line. The *posterior border* is thick, smooth, rounded, and covered by the parotid gland. The *upper border* is thin, and is surmounted

by two processes, the *coronoid* in front and the *condyloid* behind, separated by a deep concavity, the *mandibular notch*, which transmits the *masseteric nerve* and *vessels*.

The *coronoid process* is a thin, triangular eminence, which is flattened from side to side. Its *anterior border* is convex and is continuous below with the anterior border of the ramus; its *posterior border* is concave and forms the anterior boundary of the mandibular notch. Its *lateral surface* is smooth, and affords insertion to the *Masseter* and *Temporalis*. Its *medial surface* gives insertion to the *Temporalis*, and presents a ridge which begins near the apex of the process and runs downwards and forwards to the inner side of the last molar tooth. Between this ridge and the anterior border is a grooved triangular area, the upper part of which gives attachment to the *Temporalis*, the lower part to some fibres of the *Buccinator*.

The *condyloid process* is thicker than the coronoid, and consists of two portions: the *condyle*, and the constricted neck which supports it. The *condyle* articulates with the articular disc of the temporomandibular joint; it is convex from before backwards and from side to side, and its articular surface extends lower on the posterior than on the anterior surface. The long axis of the condyle is directed medialwards and slightly backwards, and if prolonged to the middle line would meet that of the opposite condyle near the anterior margin of the *foramen magnum*. At the lateral extremity of the condyle is a small tubercle for the attachment of the temporomandibular ligament. The *neck* is flattened from before backward, and strengthened by ridges which descend from the front and sides of the condyle. Its posterior surface is convex; on its anterior surface is a depression, the *pterygoid fovea*, for the attachment of the *Pterygoideus externus*.

Ossification.—The mandible is ossified in the fibrous membrane covering the outer surfaces of Meckel's cartilages. These two cartilages, a right and a left, form the cartilaginous bar of the mandibular arch (see p. 77). Their proximal or cranial ends are connected with the cartilaginous ear-capsules, and their distal extremities are joined to one another at the symphysis by mesodermal tissue. They

run forwards immediately below the mandibular condyles and then, bending downwards, lie in a groove near the lower border of the bone; in front of the canine tooth they incline upwards to the symphysis. From the proximal end of each cartilage the malleus and incus, two of the three bones of the middle ear, are developed; the next succeeding portion, as far as the lingula of the mandible,

is replaced by fibrous tissue, which forms the sphenomandibular ligament. Between the lingula and the canine tooth the cartilage disappears, whilst the portion of it below and behind the incisor teeth is ossified and incorporated with this part of the mandible.

Ossification takes place in the membrane covering the outer surfaces of Meckel's cartilages (figs. 337 to 340), and each half of the bone is formed from a single centre* which appears, near the mental foramen, about the sixth week of foetal life. By

FIG. 337.—Mandible of human embryo 24 mm. long. Outer aspect. (From model by Low.)

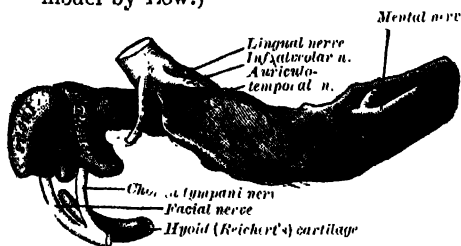
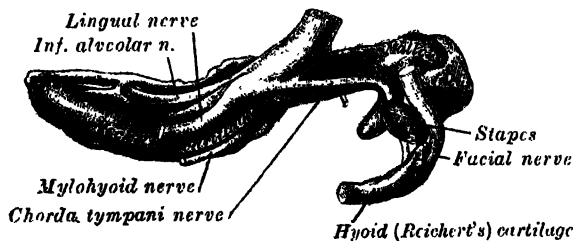


FIG. 338.—Mandible of human embryo 24 mm. long. Inner aspect. (From model by Low.)



* Low, *Proceedings of the Anatomical and Anthropological Society of the University of Aberdeen*, 1905, and *Journal of Anatomy and Physiology*, vol. xlv., and Fawcett, *Journal of the American Medical Association*, September 2, 1905.

the tenth week the portion of Meckel's cartilage which lies below and behind the incisor teeth is surrounded and invaded by the membrane-bone. Somewhat later, accessory pieces of cartilage make their appearance—viz. a wedge-shaped piece in the condyloid process and extending downwards through the ramus; a small patch along the anterior border of the coronoid process; and smaller nodules in the front part of both alveolar walls and along the front of the lower border of the bone. These accessory nodules of cartilage possess no separate ossific centres, but are invaded by the surrounding membrane-bone and undergo absorption. The inner

FIG. 339.—Mandible of human embryo 95 mm. long. Outer aspect.
(Nuclei of cartilage stippled.) (From model by Low.)

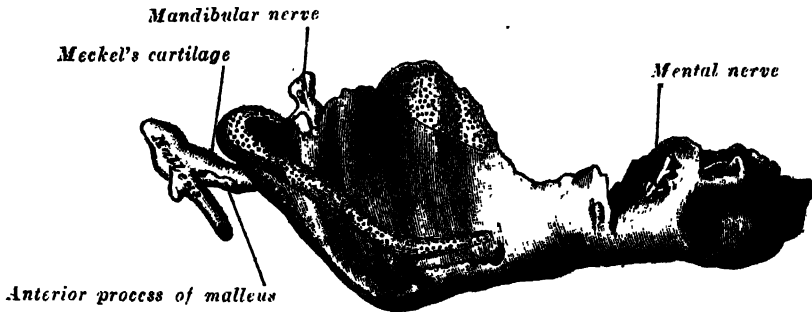
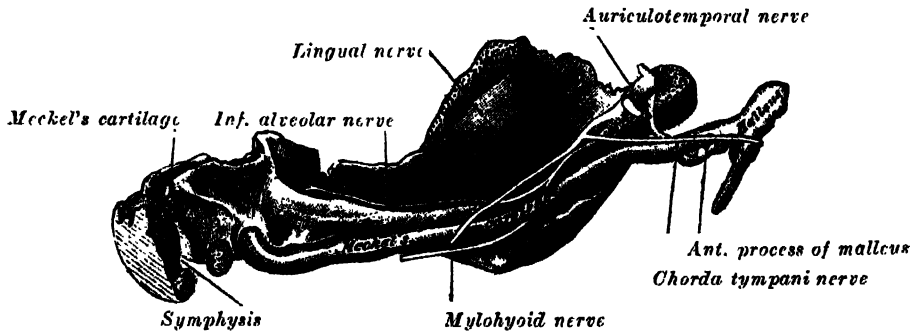


FIG. 340.—Mandible of human embryo 95 mm. long. Inner aspect.
(Nuclei of cartilage stippled.) (From model by Low.)



alveolar border, formerly described as arising from a separate *splanial* centre, is formed in the human mandible by an ingrowth from the main mass of the bone. At birth the bone consists of two parts, united by a fibrous symphysis, in which ossification takes place during the first year.

CHANGES PRODUCED IN THE MANDIBLE BY AGE.

At birth (fig. 341) the body of the bone is a mere shell, containing on either side the sockets of the deciduous teeth, imperfectly partitioned off from one another. The mandibular canal runs near the lower border of the bone, and the mental foramen opens beneath the socket of the first deciduous molar tooth. The angle is obtuse (175°), and the condyloid portion is nearly in line with the body. The coronoid process is relatively large, and projects above the level of the condyle.

After birth (fig. 342) the two segments of the bone become joined at the symphysis, from below upwards, in the first year; but a trace of separation may be visible in the beginning of the second year, near the alveolar margin. The body elongates, but more especially behind the mental foramen, to provide space for the three additional teeth developed in this part. The depth of the body increases by growth of the alveolar part of the bone, to afford room for the roots of the teeth, and by thickening of the sub-alveolar portion. After the second dentition, the mandibular canal is situated just above the level of the mylohyoid line, and the mental foramen occupies the position usual to it in the adult. By the fourth year the angle is reduced to about 140° .

SIDE VIEW OF THE MANDIBLE AT DIFFERENT PERIODS OF LIFE.

FIG. 341.—At birth.



FIG. 342.—In childhood.

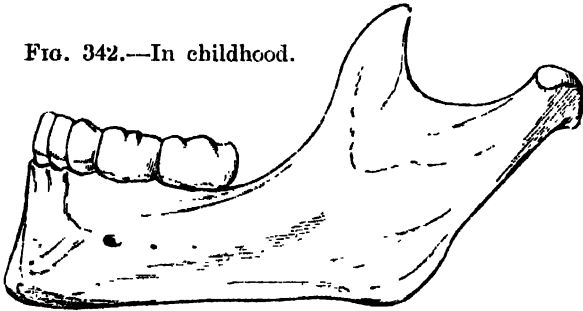


FIG. 343.—In the adult.

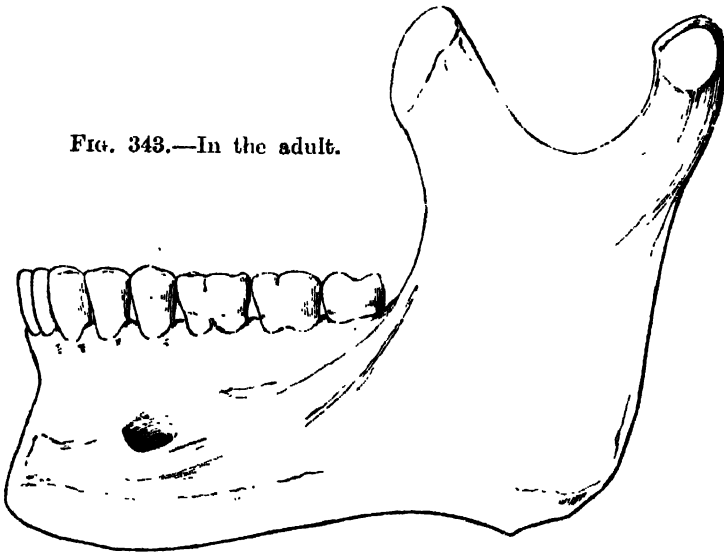
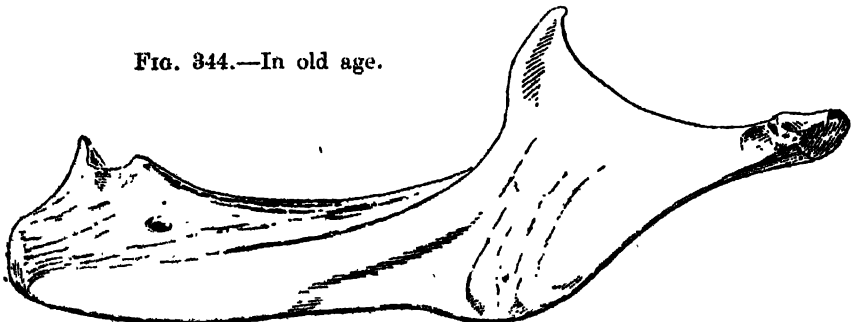


FIG. 344.—In old age.



In the adult (fig. 343) the alveolar and subalveolar portions of the body are of about equal depth. The mental foramen opens midway between the upper and lower borders of the bone, and the mandibular canal runs nearly parallel with the mylohyoid line. The ramus is almost vertical in direction, the angle measuring from 110° to 120° .

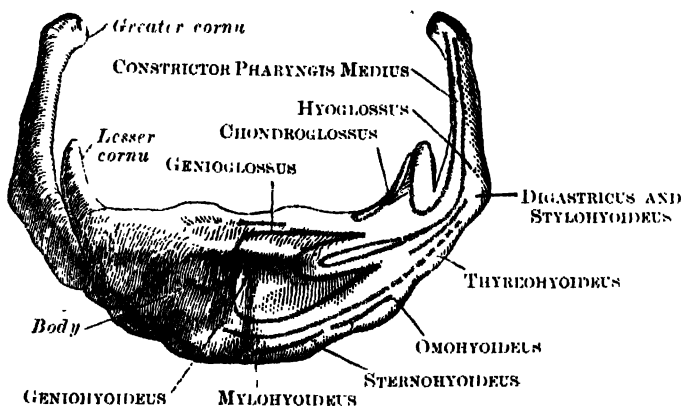
In old age (fig. 344) the bone is reduced in size, for with the loss of the teeth the alveolar process is absorbed, and, consequently, the mandibular canal and the mental foramen are close to the alveolar border. The ramus is oblique in direction, the angle measures about 140° , and the neck of the condyle is more or less bent backwards.

THE HYOID BONE (Os HYOIDEUM)

The hyoid bone (fig. 345) is shaped like a horseshoe, and is suspended from the tips of the styloid processes of the temporal bones by the stylohyoid ligaments. It consists of a body, two greater and two lesser cornua.

The body or central part is of a quadrilateral form. Its anterior surface is convex and directed forwards and upwards. It is crossed in its upper half by a well-marked transverse ridge with a slight downward convexity, and in many cases a vertical median ridge divides it into lateral halves. The portion

FIG. 345.—Hyoid bone. Anterior surface. (Enlarged.)



of the vertical ridge above the transverse line is present in a majority of specimens, but the portion below the transverse line is evident only in rare cases. The anterior surface gives insertion to the Geniohyoideus in the greater part of its extent both above and below the transverse ridge; a portion of the origin of the Hyoglossus notches the lateral margin of the Geniohyoideus attachment. Below the transverse ridge the Mylohyoideus, Sternohyoideus, and Omohyoideus are inserted. The posterior surface is smooth, concave, directed backwards and downwards, and separated from the epiglottis by the hyothyroid membrane and a quantity of loose areolar tissue; a bursa intervenes between it and the membrane. The superior border is rounded, and gives attachment to the hyothyroid membrane and some aponeurotic fibres of the Genioglossus. The inferior border affords insertion medially to the Sternohyoideus and laterally to the Omohyoideus and occasionally a portion of the Thyrohyoideus. It also gives attachment to the Levator glandulae thyroideae, when this muscle is present. In early life the lateral borders of the body are connected to the greater cornua by synchondroses; after middle life usually by bony union.

The greater cornua project backwards from the lateral borders of the body; they are flattened from above downwards and diminish in size from before backwards; each ends in a tubercle to which the lateral hyothyroid ligament is fixed. The upper surface is rough close to its lateral border, for muscular attachments: the largest of these are the origins of the Hyoglossus and Constrictor pharyngis medius which extend along the whole length of the cornu; the Digastricus and Stylohyoideus have small insertions in front of

these near the junction of the body with the cornu. To the *medial border* the hyothyroid membrane is attached, while the anterior half of the *lateral border* gives insertion to the Thyreohyoideus.

The lesser cornua are two small, conical eminences, attached by their bases to the angles of junction between the body and greater cornua. They are connected to the body of the bone by fibrous tissue and occasionally to the greater cornua by diarthrodial joints, which usually persist throughout life, but occasionally become ankylosed.

The lesser cornua are situated in the line of the transverse ridge on the body and appear to be morphological continuations of it (Parsons *). The apex of each cornu gives attachment to the stylohyoid ligament †; the Chondroglossus rises from the medial side of the base.

Ossification.—The hyoid bone is developed from the cartilages of the second and third branchial or visceral arches—the lesser cornua from the second arch, the greater cornua from the third, and the body from the fused ventral ends of both (page 78). It is ossified from six centres: two for the body, and one for each cornu. Ossification commences in the greater cornua towards the end of foetal life, in the body before or shortly after birth, and in the lesser cornua during the first or second year, or later.

EXTERIOR OF THE SKULL

The skull as a whole may be viewed from above (*norma verticalis*), from below (*norma basalis*), from the side (*norma lateralis*), from behind (*norma occipitalis*), or from the front (*norma frontalis*).

NORMA VERTICALIS

When viewed from above, the outline of the skull varies greatly in different specimens; in some it is more or less oval, in others more nearly circular. The surface is traversed by three sutures, viz.: (1) the coronal, nearly transverse in direction, between the frontal and parietal bones; (2) the sagittal, medially placed, between the parietal bones, and deeply serrated in its anterior two-thirds; and (3) the upper part of the lambdoidal, between the parietals and the occipital. The point of junction of the sagittal and coronal sutures is named the bregma, that of the sagittal and lambdoidal sutures, the lambda; they indicate respectively the positions of the anterior and posterior fonticuli in the foetal skull. On either side of the sagittal suture are the parietal tuberosity or eminence and the parietal foramen—the latter, however, is frequently absent on one or both sides. The skull is often somewhat flattened in the neighbourhood of the parietal foramina, and the term *obelion* is applied to that point of the sagittal suture which is on a level with the foramina. At the front is the glabella; lateral to it are the superciliary arches, and above these the frontal tuberosities or eminences. Immediately above the glabella the remains of the frontal suture may be seen; in about 9 per cent. of skulls this suture persists and extends along the middle line to the bregma. Passing backwards and upwards from the zygomatic processes of the frontal bone are the temporal lines, which mark the upper limits of the temporal fossæ. The zygomatic arches may or may not be seen projecting beyond the anterior portions of these lines.

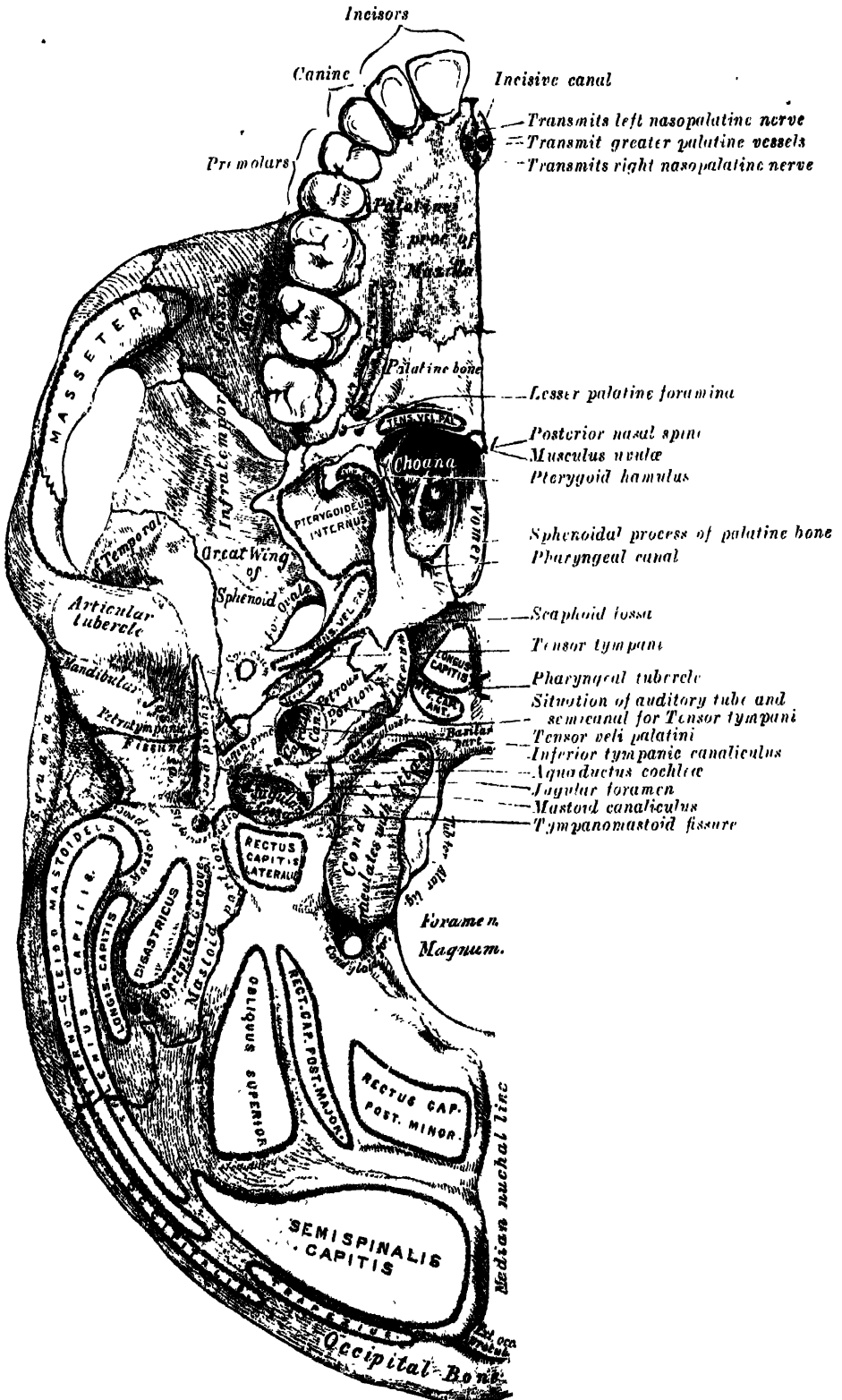
NORMA BASALIS (BASIS CRANII EXTERNA) (fig. 346)

The inferior surface of the base of the skull, exclusive of the mandible, is bounded in front by the incisor teeth in the maxillæ; behind, by the superior nuchal lines of the occipital bone; and laterally by the alveolar arch, the lower border of the zygomatic bone, the zygomatic arch and an imaginary line

* The topography and morphology of the human hyoid bone, by F. G. Parsons, *Journal of Anatomy and Physiology*, vol. xliii.

† These ligaments may undergo partial ossification.

FIG. 346.—Base of skull. Inferior surface.



drawn from the last to the mastoid process and the superior nuchal line of the occipital. The anterior part or hard palate projects below the level of the rest of the surface, and is bounded in front and laterally by the alveolar arch containing the sixteen teeth of the maxillæ. Immediately behind the incisor teeth is the incisive foramen. In this foramen are two lateral apertures, the openings of the incisive canals (foramina of Stensen); each of these leads upwards into the corresponding nasal cavity and transmits the terminal branches of the greater palatine artery and the nasopalatine nerve. Occasionally there are two additional apertures in the middle line; they are termed the foramina of Scarpa, and when present the nasopalatine nerves pass through them instead of through the foramina of Stensen, the left nerve being usually transmitted through the anterior, and the right through the posterior foramen. The vault of the hard palate is concave, uneven, perforated by numerous foramina, marked by depressions for the palatine glands, and traversed by a crucial suture formed by the junction of the four bones of which it is composed. In the young skull a suture may be present, extending on either side from the incisive foramen to the interval between the lateral incisor and canine teeth, and marking off in front of it the os incisivum or premaxillary bone. At either posterior angle of the hard palate is the greater palatine foramen, for the transmission of the greater palatine vessels and anterior palatine nerve; and running forwards and medialwards from it are two grooves, for the same vessels and nerve. Behind the greater palatine foramen is the pyramidal process of the palatine bone, perforated by two or three lesser palatine foramina, and marked by the beginning of a curved ridge for the attachment of part of the aponeurosis of the Tensor veli palatini. Projecting backwards from the middle of the posterior border of the hard palate is the posterior nasal spine, from which the Musculus uvula takes origin.

Behind and above the hard palate are the choanæ, measuring about 2.5 cm. vertically and 1.25 cm. transversely. They are separated from one another by the vomer and each is bounded above by the body of the sphenoidal bone and the vaginal process of the medial pterygoid lamina, below by the horizontal part of the palatine bone, and laterally by the medial pterygoid lamina. At the superior border of the vomer are the expanded ends of this bone, which receive between them the rostrum of the sphenoidal bone, and articulate laterally with the sphenoidal processes of the palatine bones and the vaginal processes of the medial pterygoid lamina. Above the vaginal processes are the pharyngeal canals. The medial pterygoid lamina is long and narrow; lateral to its upper part is the scaphoid fossa, for the origin of the Tensor veli palatini. At the upper end of the medial pterygoid lamina is the pterygoid tubercle, and immediately above this tubercle, the posterior end of the pterygoid canal; at the lower end of the lamina is the hamulus, around which the tendon of the Tensor veli palatini turns. The lateral pterygoid lamina is broad; its lateral surface forms the medial boundary of the infratemporal fossa, and gives origin to the Pterygoideus externus.

Behind the choanæ is the basilar portion of the occipital bone; near its centre is the pharyngeal tubercle for the attachment of the fibrous raphe of the pharynx, and on either side of the middle line are depressions for the insertions of the Rectus capitis anterior and Longus capitis. Immediately behind the upper end of the lateral pterygoid lamina is the foramen ovale, for the transmission of the mandibular nerve, the accessory meningeal artery, and sometimes the lesser superficial petrosal nerve; behind this are the foramen spinosum and the spina angularis of the sphenoidal bone; the former transmits the middle meningeal artery and the nervus spinosus, the latter gives attachment to the sphenomandibular ligament and the Tensor veli palatini. Lateral to the spina angularis is the mandibular fossa, divided into two parts by the petrotympanic fissure; the anterior portion of the fossa, concave, smooth and bounded in front by the articular tubercle, articulates with the articular disc of the temporomandibular joint; the posterior portion, bounded behind by the tympanic part of the temporal bone, is sometimes occupied by a part of the parotid gland. Emerging from the vagina processus styloidei of the tympanic part is the styloid process; and behind the upper end of this process is the stylomastoid foramen, for the exit of the facial nerve, and entrance

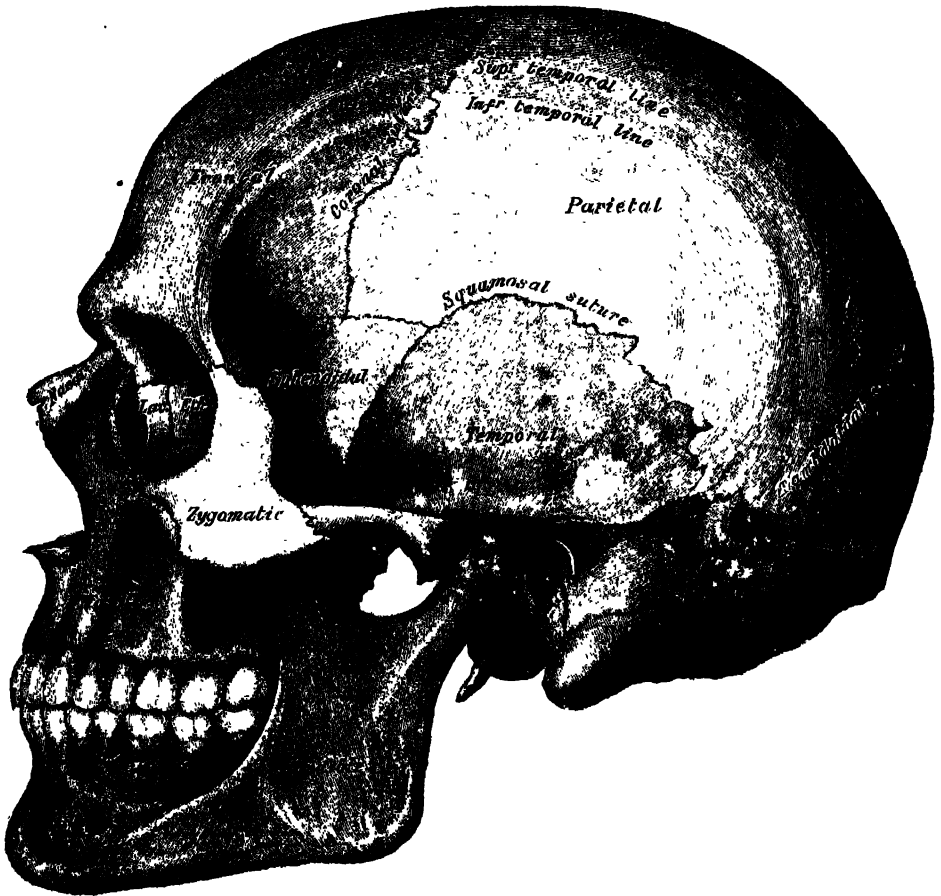
of the stylomastoid artery. Lateral to the stylomastoid foramen, between the tympanic part and the mastoid process, is the tympanomastoid fissure, which gives exit to the auricular branch of the vagus nerve. Medial to the mastoid process is the mastoid notch for the posterior belly of the Digastricus, and medial to the mastoid notch, the groove for the occipital artery. At the base of the medial pterygoid lamina is the foramen lacerum, bounded anteriorly by the great wing of the sphenoidal bone, posteriorly and laterally by the apex of the petrous portion of the temporal bone, and medially by the body of the sphenoidal bone and basilar portion of the occipital bone; it presents in front the posterior orifice of the pterygoid canal; behind, the aperture of the carotid canal. In the recent state the lower part of the foramen lacerum is filled up by a fibrocartilaginous plate, on the upper surface of which the internal carotid artery rests. Lateral to the foramen lacerum is the sulcus tubæ auditivæ, between the petrous part of the temporal bone and the great wing of the sphenoidal bone. This sulcus, directed lateralwards and backwards, lodges the cartilaginous part of the auditory tube, and is continuous behind with the semicanalis tubæ auditivæ in the temporal bone. In the floor of this sulcus is the petrosphenoidal fissure, occupied, in the recent condition, by a plate of cartilage. Behind this fissure is the under surface of the petrous portion of the temporal bone, presenting, near its apex, a quadrilateral rough surface, part of which gives origin to the Levator veli palatini; lateral to this surface is the orifice of the carotid canal, and medial to the canal, the depression leading to the aquæductus cochleæ, the former transmitting the internal carotid artery and the carotid plexus of the sympathetic, the latter serving for the passage of a vein from the cochlea. Behind the carotid canal is the jugular foramen, formed in front and laterally by the petrous portion of the temporal bone, behind and medially by the occipital bone; it is generally larger on the right than on the left side, and may be subdivided into three parts. The anterior part transmits the inferior petrosal sinus; the intermediate, the glossopharyngeal, vagus, and accessory nerves; the posterior, the transverse sinus and some meningeal branches from the occipital and ascending pharyngeal arteries. On the ridge of bone between the carotid canal and the jugular foramen is the inferior tympanic canaliculus for the transmission of the tympanic branch of the glossopharyngeal nerve; in the lateral part of the jugular foramen, near the root of the styloid process, is the mastoid canaliculus for the passage of the auricular branch of the vagus nerve. Running between the jugular foramen and the foramen lacerum is the petro-occipital fissure, occupied, in the recent state, by a plate of cartilage. Behind the basilar portion of the occipital bone is the foramen magnum which transmits the medulla oblongata and its membranes, the spinal parts of the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, and the ligaments connecting the occipital bone with the axis. Lateral to the anterior half of the foramen magnum are the occipital condyles for articulation with the atlas vertebra; the medial side of each condyle is rough for the attachment of the alar ligament. Lateral to the condyle is the jugular process, which gives attachment to the Rectus capitis lateralis. In front of the condyle is the hypoglossal canal for the passage of the hypoglossal nerve and a meningeal artery. Behind the condyle is the condyloid fossa, which is sometimes perforated by the condyloid canal, for the transmission of a vein from the transverse sinus. Behind the foramen magnum is the median nuchal line, ending above at the external occipital protuberance; on either side are the superior and inferior nuchal lines, which, with the surfaces of bone between them, are rough for the attachment of the muscles enumerated on p. 193.

NORMA LATERALIS (fig. 347)

When viewed from the side the skull is seen to consist of the cranium above and behind, and the face below and in front. The cranium is somewhat ovoid in shape, but its contour varies in different cases and depends largely on the length and height of the skull and on the degree of prominence of the superciliary arches and frontal tuberosities. Entering into its formation are the frontal, parietal, occipital, temporal, and sphenoidal bones. These bones are joined

to one another by the coronal, squamosal, parietomastoid, lambdoidal, sphenofrontal, sphenoparietal and sphenosquamosal sutures. The sphenoparietal suture varies in length in different skulls, and is absent in those cases where the frontal articulates with the temporal squama; the posterior end of the sphenoparietal suture is named the pterion. The squamosal suture arches backwards from the pterion and connects the temporal squama with the lower border of the parietal bone; it is continuous behind with the short, nearly horizontal parietomastoid suture, which unites the mastoid process of the temporal bone with the region of the mastoid angle of the parietal bone. Extending from above downwards and forwards across the cranium are the

FIG. 347.—Side view of skull.



coronal and lambdoidal sutures; the former connects the parietal bones with the frontal bone; the latter, the parietal bones with the occipital bone. The lambdoidal suture is continuous below with the occipitomastoid suture between the occipital bone and the mastoid portion of the temporal bone; in or near this suture is the mastoid foramen which transmits an emissary vein.

Immediately above the orbital margin is the superciliary arch, and, at a higher level, the frontal tuberosity. Near the centre of the parietal bone is the parietal tuberosity. Posteriorly is the external occipital protuberance, from which the superior nuchal line may be followed to the mastoid process. The temporal lines arch across the side of the cranium and mark the upper limit of the temporal fossa.

The temporal fossa is bounded above and behind by the temporal lines, which extend from the zygomatic process of the frontal bone upwards and backwards across the frontal and parietal bones, and then curve downwards

and forwards to the temporal bone to become continuous with the supra-mastoid crest and the posterior root of the zygomatic arch. The temporal fossa is bounded in front by the frontal and zygomatic bones ; opening on the latter is the zygomaticotemporal foramen. Laterally the fossa is limited by the zygomatic arch ; below, it is separated from the infratemporal fossa by the infratemporal crest on the great wing of the sphenoidal bone, and by a ridge which runs backwards from this crest across the temporal squama to the anterior root of the zygomatic process. The floor of the fossa, deeply concave in front, is formed by the zygomatic, frontal, parietal, sphenoidal, and temporal bones. It is traversed by vascular furrows : one, usually well marked, runs upwards above the opening of the external acoustic meatus, and lodges the middle temporal artery. Two others, frequently indistinct, may be observed on the anterior part of the floor, and are for the anterior and posterior deep temporal arteries. The temporal fossa contains the Temporalis muscle and its vessels and nerves, together with the zygomaticotemporal nerve.

The zygomatic arch is formed by the union of the zygomatic process of the temporal bone with the temporal process of the zygomatic bone ; the tendon of the Temporalis descends on the medial side of the arch to gain insertion into the coronoid process of the mandible. The zygomatic process of the temporal arises by two roots, an anterior, directed inwards in front of the mandibular fossa, where it expands to form the articular tubercle, and a posterior which runs backwards above the opening of the external acoustic meatus and is continuous with the supramastoid crest. The upper border of the arch gives attachment to the temporal fascia ; the lower border and medial surface give origin to the Masseter.

Below the posterior root of the zygomatic arch is the elliptical opening (porus acusticus externus) of the external acoustic meatus, bounded in front, below, and behind by the tympanic part of the temporal bone : to its circumference the cartilaginous segment of the external acoustic meatus is attached. The small triangular area between the posterior root of the zygomatic arch and the posterosuperior part of the porus acusticus is termed the suprameatal triangle, on the anterior border of which a small spinous process, the suprameatal spine, is sometimes seen. Between the tympanic part and the articular tubercle is the mandibular fossa ; behind the fossa the styloid process extends downwards and forwards for a variable distance, and gives attachment to the Styloglossus, Stylohyoideus, and Stylopharyngeus muscles, and to the stylohyoid and stylomandibular ligaments. Projecting downwards behind the porus acusticus externus is the mastoid process, to the outer surface of which the Sternocleidomastoideus, Splenius capitis, and Longissimus capitis are attached.

The *infratemporal fossa* (fig. 348) is an irregularly shaped space, situated below, and medial to, the zygomatic arch. It is bounded in front by the infratemporal surface of the maxilla, and the ridge which extends from its zygomatic process ; behind, by the articular tubercle of the temporal bone and the spina angularis of the sphenoidal bone ; above, by the great wing of the sphenoidal bone below the infratemporal crest, and by the under surface of the temporal squama ; below, by the alveolar border of the maxilla ; medially, by the lateral pterygoid lamina. It contains the lower part of the Temporalis, the Pterygoidei internus and externus, the internal maxillary vessels, and the mandibular and maxillary nerves. The foramen ovale and foramen spinosum open on its roof, and the alveolar canals, on its anterior wall. At its upper and medial part are two fissures, which together form a rectangular fissure, the horizontal limb being the inferior orbital, and the vertical one the pterygo-maxillary.

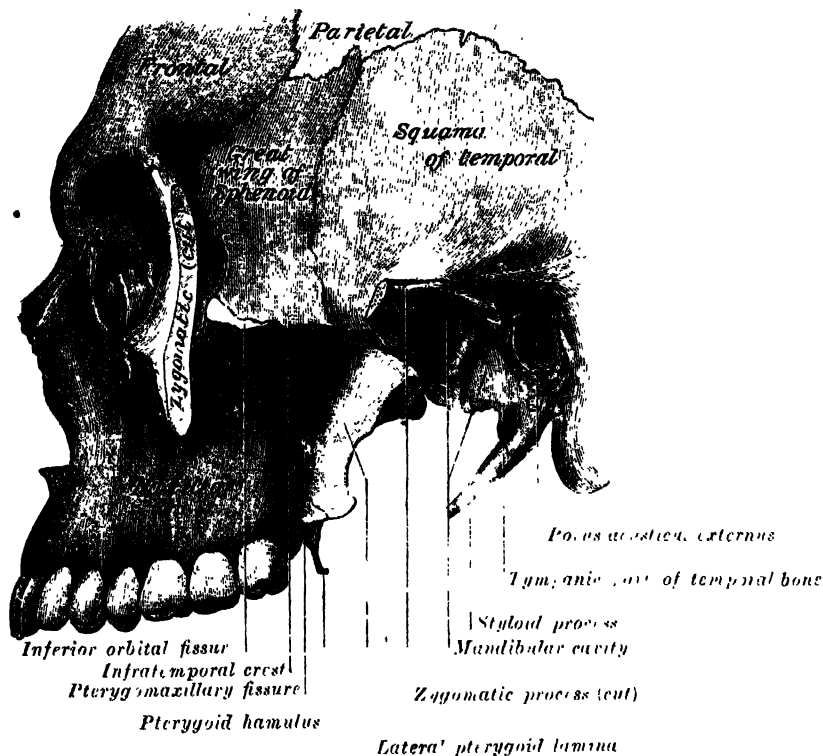
The *inferior orbital fissure* (sphenomaxillary fissure), nearly horizontal in direction, opens into the lateral and back part of the orbit. It is bounded above by the lower border of the orbital surface of the great wing of the sphenoidal bone ; below, by the lateral border of the orbital surface of the maxilla and the orbital process of the palatine bone ; laterally, by a small part of the zygomatic bone* ; medially, it joins at right angles with the pterygomaxillary fissure. Through the inferior orbital fissure the orbit communicates with the infra-

* Sometimes the maxilla and the sphenoidal bone articulate with each other at the lateral extremity of this fissure ; the zygomatic is then excluded from it.

temporal and pterygopalatine fossæ; the fissure transmits the maxillary nerve and its zygomatic (temporomalar) branch, the infraorbital vessels, the orbital branches of the sphenopalatine ganglion, and a vein which connects the inferior ophthalmic vein with the pterygoid venous plexus.

The pterygomaxillary fissure is vertical, and descends at right angles from the medial end of the preceding; it is a triangular interval, formed by the divergence of the maxilla from the pterygoid process of the sphenoidal bone. It connects the infratemporal with the pterygopalatine fossa, and transmits the terminal part of the internal maxillary artery.

FIG. 348.—Left infratemporal fossa.



The pterygopalatine fossa (sphenomaxillary fossa) (fig. 351) is a small, triangular space at the angle of junction of the inferior orbital and pterygomaxillary fissures, and placed beneath the apex of the orbit. It is bounded above by the under surface of the body of the sphenoidal bone and by the orbital process of the palatine bone; in front, by the upper part of the infratemporal surface of the maxilla; behind, by the base of the pterygoid process and lower part of the anterior surface of the great wing of the sphenoidal bone; medially, by the vertical part of the palatine bone with its orbital and sphenoidal processes. The fossa contains the maxillary nerve, the sphenopalatine ganglion and the terminal part of the internal maxillary artery. Five foramina open into it. Of these, three are on the posterior wall, viz.: the foramen rotundum, the pterygoid canal, and the pharyngeal canal, in this order downwards and medialwards; on the medial wall is the sphenopalatine foramen; below is the superior orifice of the pterygopalatine canal.

NORMA OCCIPITALIS

When viewed from behind, the cranium presents a more or less circular outline. In the middle line above is the posterior part of the sagittal suture connecting the parietal bones; extending downwards and lateralwards from

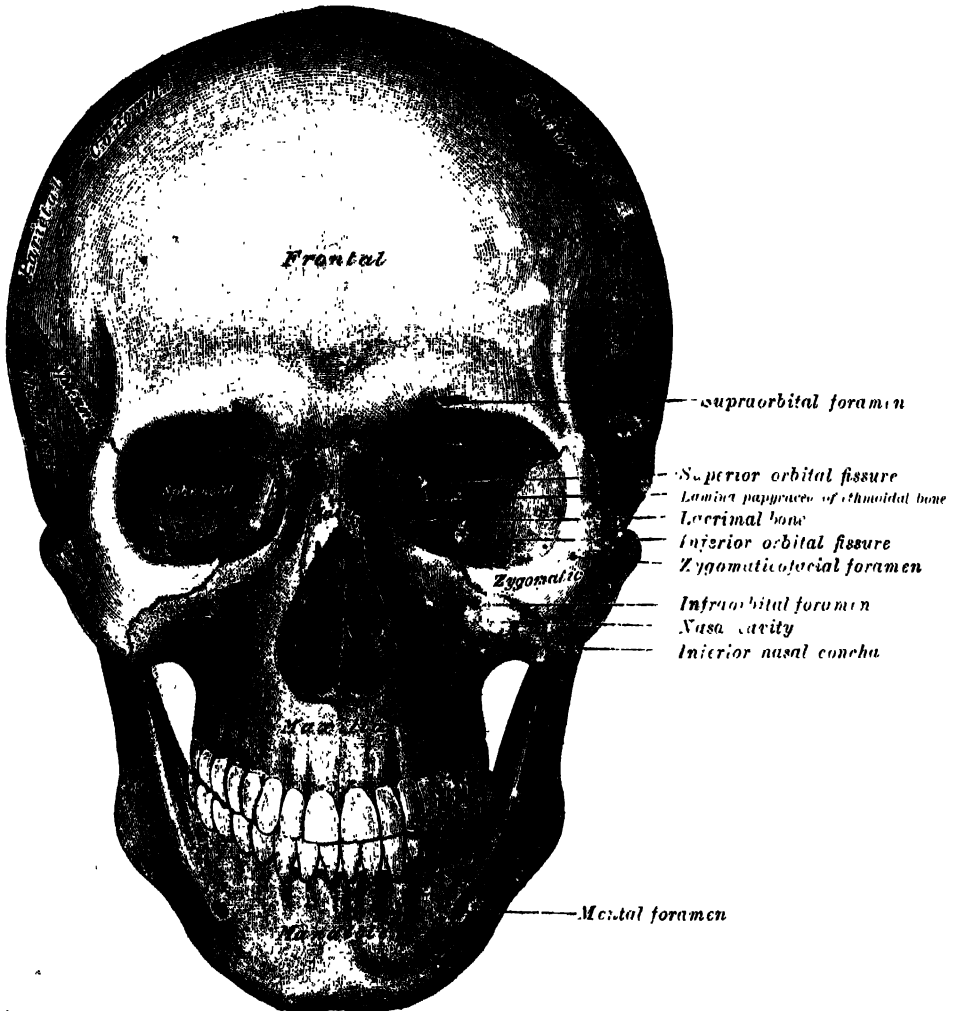
the posterior end of this suture is the deeply serrated lambdoidal suture joining the parietals to the occipital and continuous below with the parietomastoid and occipitomastoid sutures; it frequently contains one or more sutural bones. Near the middle of the occipital squama is the external occipital protuberance or inion, and, extending lateralwards from it, the superior nuchal lines, and above these the faintly marked highest nuchal lines. The outer surface of the part of the occipital bone above the inion and highest nuchal lines is named the planum occipitale, and is covered by the Occipitalis muscle; the outer surface of the part below is termed the planum nuchale, and is divided by the medial nuchal line which runs downwards and forwards from the inion to the foramen magnum; this line gives attachment to the ligamentum nuchæ. The muscles attached to the planum nuchale are enumerated on p. 193. Below and in front are the mastoid processes, convex laterally and grooved medially by the mastoid notches. In or near the occipitomastoid suture is the mastoid foramen for the passage of the mastoid emissary vein.

NORMA FRONTALIS (fig. 349)

When viewed from the front, the skull exhibits a somewhat oval outline, limited above by the frontal bone, below by the body of the mandible, and laterally by the zygomatic bones and the mandibular rami. The upper part, formed by the frontal squama, is smooth and convex. The lower part, made up of the bones of the face, is irregular; it is excavated laterally by the orbital cavities, and presents in the middle the anterior nasal aperture leading to the nasal cavities, and below this the transverse slit between the upper and lower dental arcades. The frontal tuberosities stand out more or less prominently, and beneath these are the superciliary arches, the medial ends of which are joined to one another by the glabella. On and above the glabella a trace of the frontal suture sometimes persists; beneath the glabella is the frontonasal suture, below and behind which are the frontomaxillary and frontolacrimal sutures. Below each superciliary arch is the upper part of the margin of the base of the orbit, thin and prominent in its lateral two-thirds, rounded in its medial third, and displaying at the junction of these two portions the supraorbital notch or foramen for the supraorbital nerve and vessels. The supraorbital margin ends laterally in the zygomatic process, from which the temporal lines extend upwards and backwards. Below the frontonasal suture is the bridge of the nose, convex from side to side, concavo-convex from above downwards, and formed by the two nasal bones supported in the middle line by the nasal spine of the frontal and the lamina perpendicularis of the ethmoidal bone. The frontal processes of the maxillæ ascend between the nasal and lacrimal bones and form the lower and medial parts of the circumferences of the orbits. Below the nasal bones and between the maxillæ is the anterior aperture of the nasal cavity, pyriform in shape, with the narrow end directed upwards. Laterally this aperture is bounded by sharp margins which curve medialwards and forwards and end in the anterior nasal spine. On looking into the nasal cavity, the bony septum between the right and left nasal chambers presents, in front, a large triangular deficiency; this is filled in the recent state by the cartilage of the nasal septum; on the lateral wall of each nasal cavity the anterior part of the inferior nasal concha is visible. Below and lateral to the anterior nasal aperture are the anterior surfaces of the maxillæ, each perforated, near the lower margin of the orbit, by the infraorbital foramen for the passage of the infraorbital nerve and vessels. Below and medial to this foramen is the canine eminence separating the incisive from the canine fossa. Beneath these fossæ are the alveolar processes of the maxillæ containing the upper teeth, which overlap the teeth of the mandible in front. The zygomatic bone on either side forms the prominence of the cheek, the lower and lateral portion of the orbital cavity, and the anterior part of the zygomatic arch. It articulates medially with the maxilla, behind with the zygomatic process of the temporal bone, and the great wing of the sphenoidal bone, and above with the zygomatic process of the frontal bone; it is perforated by the zygomaticofacial foramen for the passage of the zygomaticofacial nerve. On the upper part of the body of the mandible is a median ridge, indicating the position of the symphysis;

this ridge divides below to enclose the mental protuberance, the lateral angles of which constitute the mental tubercles. Below the incisor teeth is the incisive fossa, and beneath the second premolar tooth the mental foramen which transmits the mental nerve and vessels. The oblique line ascends from the mental tubercle and is continuous behind with the anterior border of the ramus. The posterior border of the ramus runs downwards and forwards from the condyle to the angle, which is frequently more or less everted.

FIG. 349.—The skull from the front.



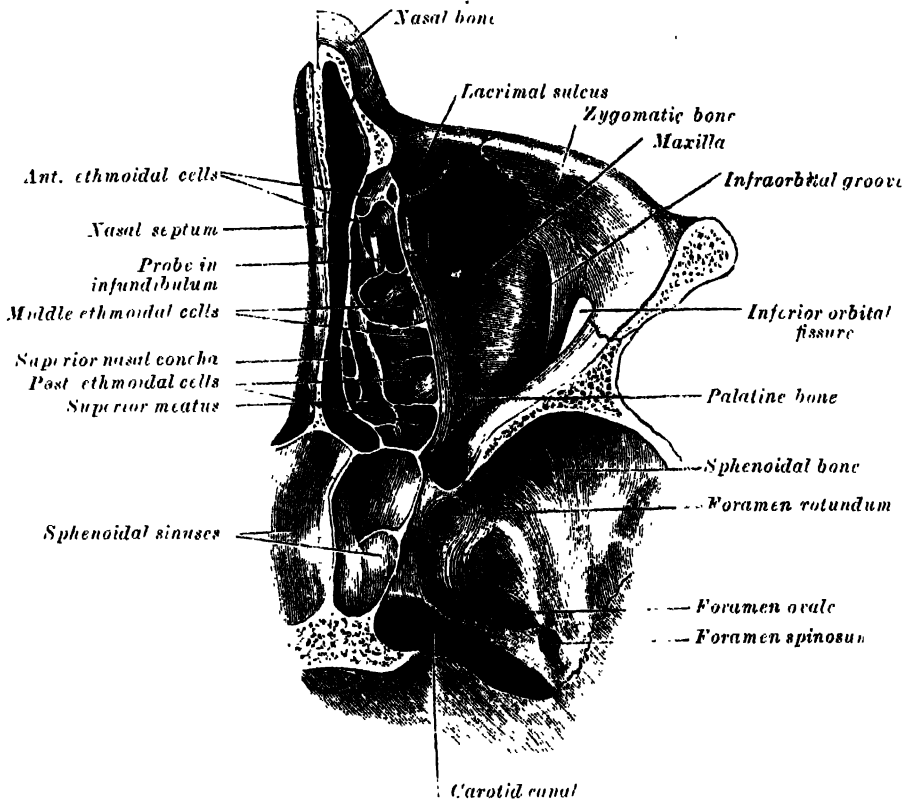
The orbits (fig. 349) are two quadrilateral pyramidal cavities, situated at the upper and anterior part of the face, their bases being directed forwards and lateralwards, and their apices backwards and medialwards, so that their long axes, if continued backwards, would meet over the body of the sphenoidal bone. Each has a roof, a floor, a medial and a lateral wall, a base, and an apex.

The roof of the orbit is concave, directed downwards and slightly forwards, and formed in front by the orbital plate of the frontal bone, behind by the small wing of the sphenoidal bone. It presents, just within the base of the orbit and about midway between the supraorbital notch and the frontolacrimal suture, a small depression or spine, the fovea vel spina trochlearis, for the attachment of the cartilaginous pulley of the Obliquus oculi superior; on its

anterolateral part is the lacrimal fossa for the lacrimal gland ; posteriorly is the suture between the frontal bone and the small wing of the sphenoidal bone.

The floor of the orbit (fig. 350) looks upwards and lateralwards, and is of less extent than the roof ; it is formed chiefly by the orbital surface of the maxilla : in front and laterally, by the orbital process of the zygomatic bone ; behind and medially, to a small extent, by the orbital process of the palatine bone. At its medial angle is the upper opening of the nasolacrimal canal, immediately to the lateral side of which is a depression for the origin of the Obliquus oculi inferior. On its lateral part is the suture between the maxilla

FIG. 350.—Horizontal section of nasal and orbital cavities, viewed from above.

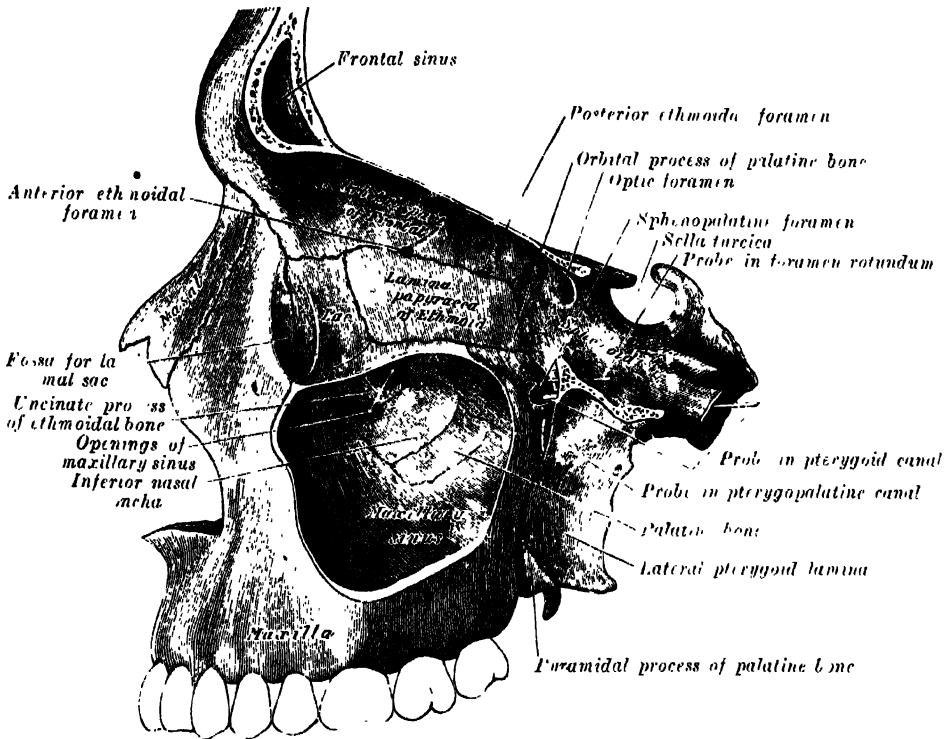


and zygomatic bone, and at its posterior part that between the maxilla and the orbital process of the palatine bone. Running forwards near the middle of the floor is the infraorbital groove, ending anteriorly in the infraorbital canal and transmitting the infraorbital nerve and vessels.

The medial wall of the orbit (fig. 351) is nearly vertical, and is formed from before backwards by the frontal process of the maxilla, the lacrimal, the lamina papyracea of the ethmoidal bone, and a small portion of the body of the sphenoidal bone in front of the optic foramen ; sometimes the sphenoidal concha forms a small part of this wall (see p. 202). It exhibits three vertical sutures—viz. : the lacrimomaxillary, lacrimo-ethmoidal, and speno-ethmoidal. In front is seen the lacrimal fossa, which lodges the lacrimal sac, and behind the fossa is the posterior lacrimal crest, from which the lacrimal part of the Orbicularis oculi arises. At the junction of the medial wall and the roof are the frontomaxillary, frontolacrimal, fronto-ethmoidal, and frontosphenoidal sutures. In the fronto-ethmoidal suture are the anterior and posterior ethmoidal foramina, the former transmitting the anterior ethmoidal nerve and vessels, the latter the posterior ethmoidal nerve and vessels.

The *lateral wall* of the orbit, directed medialwards and forwards, is formed by the orbital surface of the zygomatic bone and the orbital surface of the great wing of the sphenoidal bone; these are united by the sphenozygomatic suture which terminates below at the anterior end of the inferior orbital fissure. On the orbital process of the zygomatic bone are the orbital tubercle (Whitnall) and the orifices of one or two canals which transmit the branches of the zygomatic nerve. Between the roof and the lateral wall, near the apex of the orbit, is the superior orbital fissure. Through this fissure the oculomotor, the trochlear, the ophthalmic, and the abducent nerves enter the orbital cavity, also some filaments from the cavernous plexus of the sympathetic and the

FIG. 351.—Medial wall of left orbit.



orbital branches of the middle meningeal artery. The ophthalmic veins and the recurrent branch from the lacrimal artery to the dura mater leave the orbit through this fissure. The lateral wall and the floor of the orbit are separated posteriorly by the inferior orbital fissure which transmits the maxillary nerve and its zygomatic branch, the infraorbital vessels, and the ascending branches of nerves from the sphenopalatine ganglion.

The *base* of the orbit, quadrilateral in shape, is formed above by the supra-orbital arch of the frontal bone, in which is the supraorbital notch or foramen for the passage of the supraorbital vessels and nerve; below by the zygomatic bone and maxilla, united by the zygomaticomaxillary suture; laterally by the zygomatic bone and the zygomatic process of the frontal bone joined by the zygomaticofrontal suture; medially by the frontal bone and the frontal process of the maxilla united by the frontomaxillary suture.

The *apex* of the orbit corresponds to the optic foramen,* a short canal, through which the optic nerve and ophthalmic artery enter the orbital cavity.

* Some anatomists describe the apex of the orbit as corresponding with the medial end of the superior orbital fissure. It seems better, however, to adopt the statement in the text, since the Recti muscles take origin around the optic foramen, and diverge from it to the bulb of the eye.

INTERIOR OF THE SKULL

In order to study the interior of the skull, the skull-cap should be removed by a saw-cut carried round the cranium about the level of the frontal eminences and the upper limits of the squamosal sutures, cutting the occipital bone about 2.5 cm. above the external protuberance.

INNER SURFACE OF THE SKULL-CAP

On the concave inner surface of the skull-cap are depressions for the convolutions of the cerebrum and numerous furrows for the branches of the meningeal vessels. In the middle line is the sagittal sulcus, narrow in front, and broad behind; it lodges the superior sagittal sinus, and its margins afford attachment to the falx cerebri. On either side of it are several depressions for the arachnoideal granulations, and, at its posterior part, the openings of the parietal foramina when these are present. It is crossed in front by the coronal suture, and behind by the lambdoidal suture, whilst the sagittal suture lies in the median plane between the parietal bones.

UPPER SURFACE OF THE BASE OF THE SKULL (BASIS CRANII INTERNA) (fig. 352)

The upper surface of the base of the skull, or floor of the cranial cavity, is divided into anterior, middle, and posterior cranial fossæ.

Anterior fossa.—The floor of this fossa is formed by the orbital plates of the frontal bone, the lamina cribrosa of the ethmoidal bone, the small wings and anterior part of the body of the sphenoidal bone; it is limited behind by the posterior borders of the small wings of the sphenoidal bone and by the anterior margin of the sulcus chiasmatis. It is traversed by the fronto-ethmoidal, spheno-ethmoidal and sphenofrontal sutures. Its lateral portions roof in the orbital cavities and support the frontal lobes of the cerebrum; they are convex and marked by depressions for the brain convolutions, and by grooves for branches of the meningeal vessels. The central portion corresponds with the roof of the nasal cavity, and is markedly depressed on either side of the crista galli. It presents, in the median line, from before backwards, the commencement of the frontal crest for the attachment of the falx cerebri; the foramen cæcum, which usually transmits a small vein from the nasal cavity to the superior sagittal sinus; the crista galli, the free margin of which affords attachment to the anterior end of the falx cerebri. On either side of the crista galli is the olfactory groove formed by the lamina cribrosa of the ethmoidal bone, which supports the olfactory bulb and is perforated by foramina for the transmission of the olfactory nerves; at the front part of this lamina is the foramen for the anterior ethmoidal nerve. Lateral to either olfactory groove are the internal openings of the anterior and posterior ethmoidal foramina; the anterior, situated about the middle of the lateral margin of the olfactory groove, transmits the anterior ethmoidal nerve and vessels; the nerve runs in a groove along the lateral edge of the lamina cribrosa to the foramen above mentioned; the posterior ethmoidal foramen opens at the posterior part of this margin under cover of a projecting lamina of the sphenoidal bone, and transmits the posterior ethmoidal nerve and vessels. Posteriorly the anterior margin of the sulcus chiasmatis runs lateralwards to the upper margins of the optic foramina.

The middle fossa, deeper than the preceding, is narrow in the middle, and wide at the sides of the skull. It is bounded in front by the posterior margins of the small wings of the sphenoidal bone, the anterior clinoid processes, and the ridge forming the anterior margin of the sulcus chiasmatis; behind, by the dorsum sellæ of the sphenoidal bone and the superior angles of the petrous portions of the temporals; laterally by the temporal squamæ, the sphenoidal angles of the parietal bones, and the great wings of the sphenoidal bone. It is traversed by the squamosal, sphenoparietal, sphenosquamosal, and sphenopetrous sutures.

The middle part of the fossa presents, in front, the sulcus chiasmatis and tuberculum sellæ; the sulcus ends on either side at the optic foramen, which

FIG. 352.—Base of the skull. Upper surface.



transmits the optic nerve and ophthalmic artery to the orbital cavity. Behind the optic foramen the anterior clinoid process is directed backwards and medialwards and gives attachment to the tentorium cerebelli. Behind the tuberculum sellæ is a deep depression, the sella turcica, containing the fossa hypophyseæ.

which lodges the hypophysis, and presents at the lateral angles of its anterior wall the middle clinoid processes. The sella turcica is bounded posteriorly by the dorsum sellæ, the upper angles of which are surmounted by the posterior clinoid processes: these afford attachment to the tentorium cerebelli, and some little distance below each is a notch on the side of the dorsum sellæ for the abducent nerve. Lateral to the sella turcica is the carotid sulcus, which begins behind at the foramen lacerum, and ends on the medial side of the anterior clinoid process, where it is sometimes converted into a foramen (carotico-clinoid) by the union of the anterior and middle clinoid processes; the posterior part of the sulcus is bounded anterolaterally by the lingula. The carotid sulcus lodges the cavernous sinus and the internal carotid artery, the latter being surrounded by a plexus of sympathetic nerves.

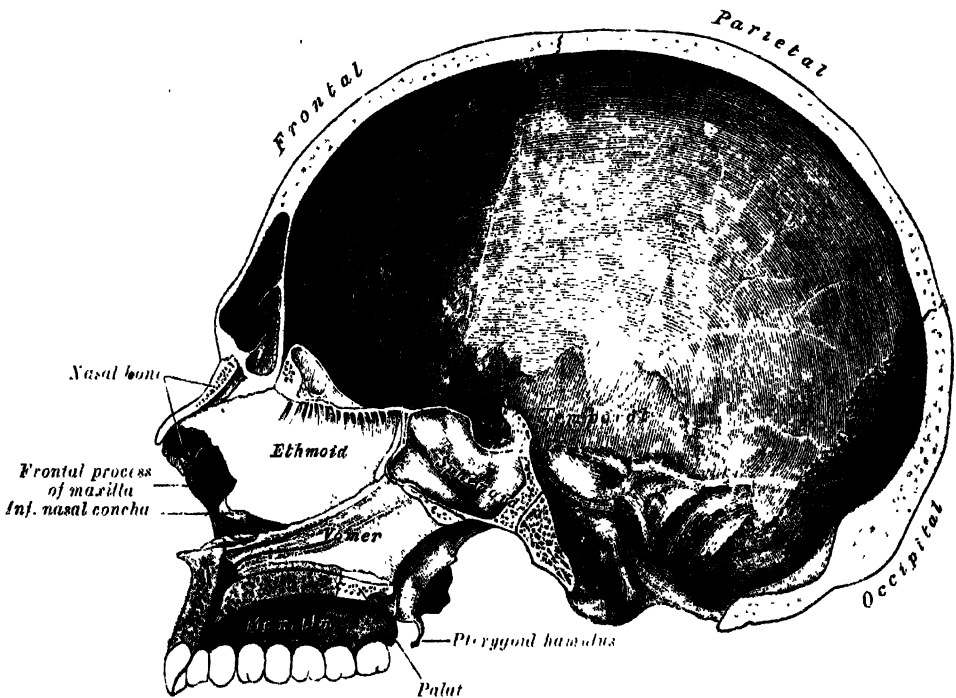
The lateral parts of the middle fossa are deep, and support the temporal lobes of the brain. They are marked by deep depressions for the brain convolutions, and traversed by furrows for the anterior and posterior branches of the middle meningeal vessels. These furrows begin by the bifurcation of a groove which runs for about 2 cm. forwards and lateralwards from the foramen spinosum; the anterior furrow is directed forwards and upwards to the sphenoidal angle of the parietal bone, where it is sometimes converted into a bony canal; the posterior arches backwards across the temporal squama and passes on to the parietal bone near the middle of its lower border. The following apertures are also present. In front is the superior orbital fissure, bounded above by the small wing, below by the great wing and medially by the body of the sphenoidal bone; it is usually completed laterally by the orbital plate of the frontal bone. It transmits to the orbital cavity the oculomotor, the trochlear, the ophthalmic division of the trigeminal, and the abducent nerves, some filaments from the cavernous plexus of the sympathetic, and the orbital branch of the middle meningeal artery; and from the orbital cavity a recurrent branch from the lacimal artery to the dura mater, and the ophthalmic veins. Behind the medial end of the superior orbital fissure is the foramen rotundum, for the passage of the maxillary nerve. Posterior and lateral to the foramen rotundum is the foramen ovale, which transmits the mandibular nerve, the accessory ophthalmic artery, and the lesser superficial petrosal nerve.* Medial to the foramen ovale is the foramen Vesalii, which varies in size, and is often absent; when present, it opens below at the lateral side of the scaphoid fossa, and transmits a small vein. Lateral to the foramen ovale is the foramen spinosum, for the passage of the nervus spinosus and the middle meningeal artery. Medial to the foramen ovale is the foramen lacerum; in the recent state the lower part of this foramen is filled by a fibrocartilaginous plate, on the upper surface of which rests the internal carotid artery, surrounded by a plexus of sympathetic nerves, the nerve of the pterygoid canal, and a meningeal branch from the ascending pharyngeal artery, pierce the fibrocartilaginous plate. On the anterior surface of the petrous portion of the temporal bone is the eminentia arcuata caused by the upward projection of the superior semicircular canal; in front of and a little lateral to this, a depressed area forming the roof of the tympanic cavity; the groove leading to the hiatus of the facial canal, for the transmission of the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery; lateral to it, the smaller groove for the passage of the lesser superficial petrosal nerve; and, near the apex of the bone, the depression for the semilunar ganglion, and the orifice of the carotid canal.

The posterior fossa, the largest and deepest, is formed by the dorsum sellæ of the sphenoidal bone, the basilar and lateral parts of the occipital bone, the petrous and mastoid portions of the temporal bones, the mastoid angles of the parietal bones, and the lower part of the squama occipitalis; it lodges the cerebellum, pons, and medulla oblongata, and is crossed by the petro-occipital, occipitomastoid, and parietomastoid sutures. It is separated from the middle fossa in and near the median line by the dorsum sellæ of the sphenoidal bone, and on either side by the superior angle of the petrous portion of the temporal bone. This angle gives attachment to the tentorium cerebelli, is grooved for the superior petrosal sinus, and is notched at its medial end for the trigeminal nerve. The posterior fossa is limited behind

* See footnote, p. 200.

by the transverse sulci of the occipital bone. In its centre is the foramen magnum, and on either side of this foramen is a rough tubercle for the attachment of the alar ligaments; a little above this tubercle is the hypoglossal canal which transmits the hypoglossal nerve and a meningeal branch from the ascending pharyngeal artery. In front of the foramen magnum the basilar portion of the occipital bone and the posterior part of the body of the sphenoidal bone form the *clivus* which supports the medulla oblongata and pons; in the young skull these bones are joined by a *synchondrosis*. This grooved surface is separated on either side from the petrous portion of the temporal bone by the petro-occipital fissure, which is occupied in the recent state by a plate of cartilage; the fissure is continuous behind with the jugular foramen, and its margins are grooved for the inferior petrosal sinus. The jugular foramen is situated between the lateral part of the occipital bone and the petrous part of the temporal bone. The anterior portion of this foramen transmits the

FIG. 353.—Sagittal section of skull.



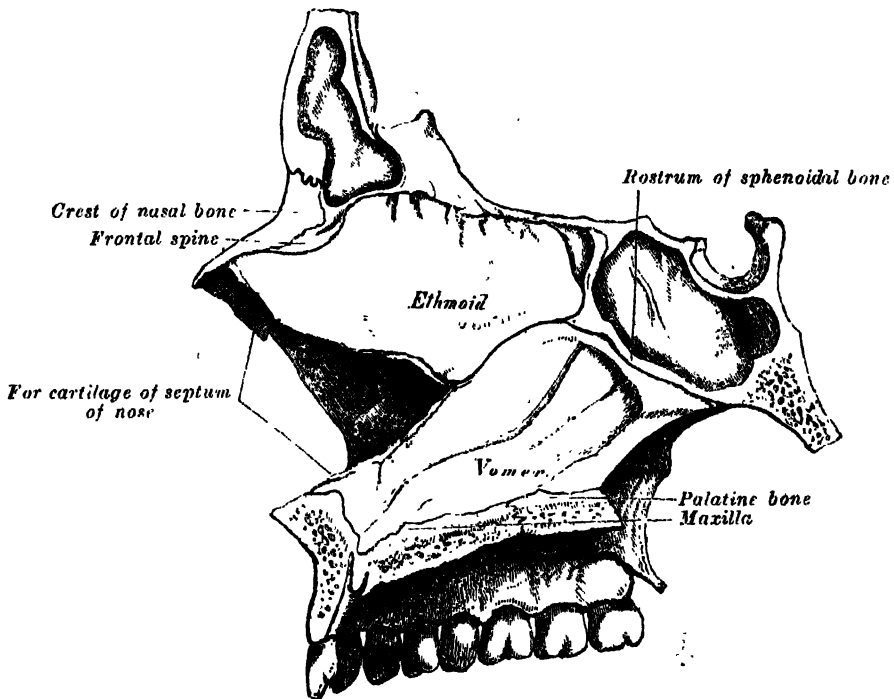
inferior petrosal sinus; the posterior portion, the transverse sinus and some meningeal branches from the occipital and ascending pharyngeal arteries; and the intermediate portion, the glossopharyngeal, vagus, and accessory nerves. Above the jugular foramen is the opening of the internal acoustic meatus, for the facial and acoustic nerves and internal auditory artery; behind and lateral to this opening is the slit leading to the aquæductus vestibuli, which lodges the ductus endolymphaticus; while between these, and near the superior angle of the petrous portion, is a small triangular depression, the remains of the fossa subarcuata, which lodges a process of the dura mater and occasionally transmits a small vein. Behind the foramen magnum is the internal occipital crest which serves for the attachment of the falx cerebelli; in the attached margin of this falx is the occipital sinus, which is sometimes duplicated. Lateral to the crest are the inferior occipital fossæ which support the hemispheres of the cerebellum and are limited behind by the transverse sulci. Each of the transverse sinuses, in its passage to the jugular foramen, grooves the occipital bone, the mastoid angle of the parietal bone, the mastoid portion of the temporal bone, and the jugular process of the occipital bone, and ends at the posterior part of the jugular foramen. Where the sinus grooves the mastoid portion

of the temporal bone, the orifice of the mastoid foramen may be seen; and just behind the jugular foramen, the condyloid canal opens into it; neither opening is constant.

THE NASAL CAVITIES

The **nasal cavities** are two irregular spaces, situated one on either side of the middle line of the face, extending from the base of the cranium to the roof of the mouth, and separated from each other by a thin vertical septum. They open on the face through the pear-shaped anterior nasal aperture, and their posterior openings, or choanæ, communicate, in the recent state, with the nasal part of the pharynx. They are much narrower above than below, and in the middle than at their anterior or posterior openings: their depth

FIG. 354.—Medial wall of left nasal cavity.



is greatest in the middle. They communicate with the frontal, ethmoidal, sphenoidal, and maxillary sinuses. Each cavity has a roof, a floor, a medial and a lateral wall.

The *roof* (figs. 354, 355) is horizontal in its central part, but slopes downwards in front and behind; it is formed in front by the nasal bone and the frontal spine; in the middle, by the lamina cribrosa of the ethmoidal bone; and behind, by the body of the sphenoidal bone, the sphenoidal concha, the ala of the vomer and the sphenoidal process of the palatine bone. In the lamina cribrosa are the foramina for the olfactory nerves, and in front of these is the foramen for the anterior ethmoidal nerve; on the posterior part of the roof is the opening into the sphenoidal sinus.

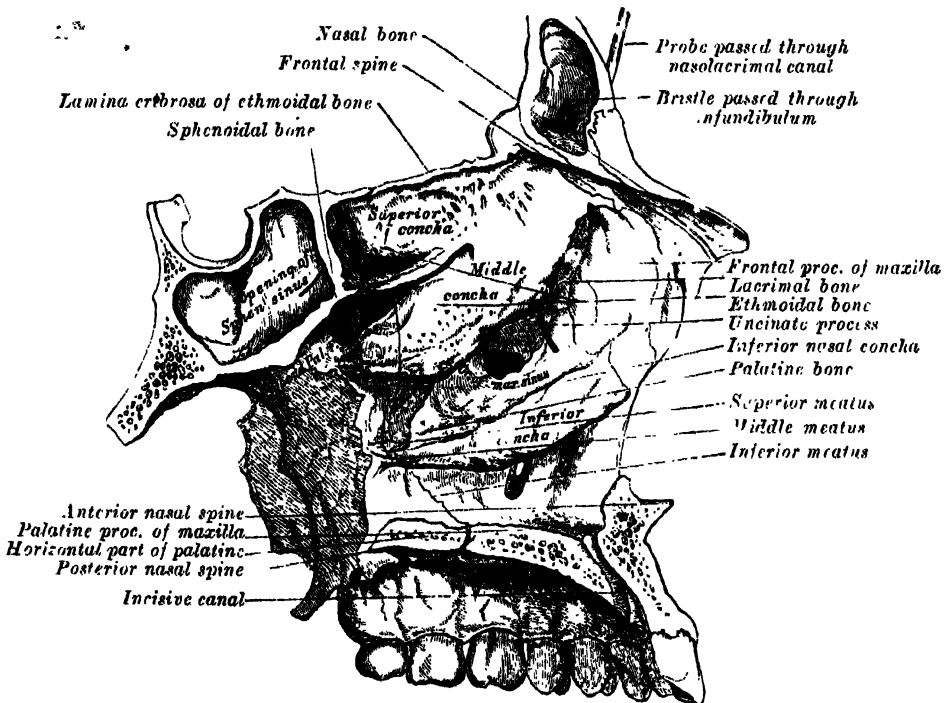
The *floor*, flattened from before backwards and concave from side to side, is formed by the palatine process of the maxilla and the horizontal part of the palatine bone; near its anterior end is the opening of the incisive canal.

The *medial wall*, or *septum nasi* (fig. 354), is frequently deflected to one or other side, more often to the left than to the right. It is formed, in front, by the crest of the nasal bones and the frontal spine; in the middle, by the lamina perpendicularis of the ethmoidal bone; behind, by the vomer and by the

strum of the sphenoidal bone ; below, by the crest of the maxillæ and palatine bones. In front is a large, triangular notch which is filled by the cartilage of the septum ; behind, is the free edge of the vomer. Its surface is marked by furrows for vessels and nerves, and the vomer is grooved for the nasopalatine nerve.

The *lateral wall* (fig. 355) is formed, in front, by the nasal bone, the frontal process of the maxilla, and the lacrimal bone ; in the middle, by the ethmoidal bone, maxilla, and inferior nasal concha ; behind, by the vertical part of the palatine bone, and the medial pterygoid lamina of the sphenoidal bone. On this wall are three irregular, anteroposterior passages, termed the superior, middle, and inferior meatuses of the nose. The superior meatus, the smallest of the three, occupies the middle third of the lateral wall. It lies between the superior and middle nasal conchæ ; the sphenopalatine foramen opens into

FIG. 355.—Roof, floor, and lateral wall of left nasal cavity.



it behind, and the posterior ethmoidal cells in front. Above and behind the superior concha is a triangular depression named the sphenothmoidal recess, into which the sphenoidal sinus opens. The middle meatus is situated between the middle and inferior conchæ, and extends from the anterior to the posterior end of the latter. The lateral wall of this meatus can be satisfactorily studied only after the removal of the middle concha. On it is a curved fissure, the *hiatus semilunaris*, limited below by the edge of the uncinate process of the ethmoidal bone, and above by an elevation named the *bulla ethmoidalis* ; the middle ethmoidal cells are contained within this bulla and open on, or near to it. Through the hiatus semilunaris the meatus opens into a curved passage termed the *infundibulum* ; this communicates in front with the anterior ethmoidal cells, and in rather more than fifty per cent. of skulls is continuous above with the frontonasal duct which opens into the frontal air-sinus ; when this continuity fails through the fusion of the bulla ethmoidalis with the uncinate process of the ethmoidal bone, the frontonasal duct opens directly into the anterior part of the meatus. Below the bulla ethmoidalis and hidden by the uncinate process of the ethmoidal bone is the *ostium maxillare* or opening of the maxillary sinus ; an accessory opening from the sinus is frequently

present above the posterior part of the inferior nasal concha. The *inferior meatus*, the largest of the three, is the space between the inferior concha and the floor of the nasal cavity. It extends almost the entire length of the lateral wall of the nose, is broader in front than behind, and presents anteriorly the lower orifice of the nasolacrimal canal.

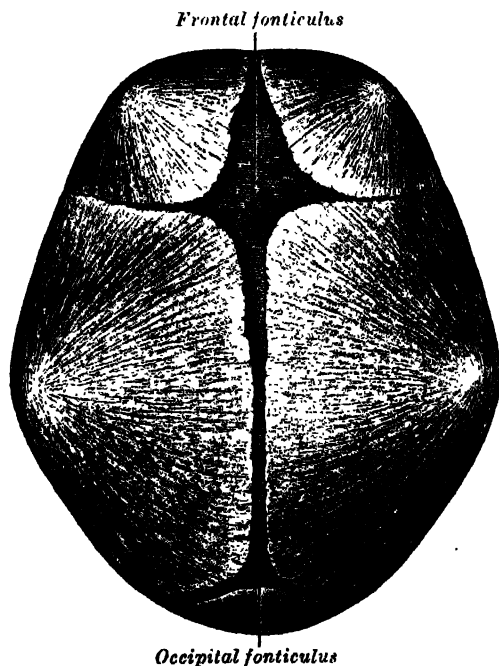
The *apertura piriformis*, or *anterior nasal aperture* (fig. 350), is bounded above by the inferior borders of the nasal bones; laterally by the thin, sharp margins which separate the anterior from the nasal surfaces of the maxillæ; and below by the same borders, where they curve medialwards to join each other at the anterior nasal spine. In the recent state it is much contracted by the lateral and alar cartilages of the nose.

The *choana* or *posterior nasal apertures* are each bounded above by the ala of the vomer and the vaginal process of the medial pterygoid lamina; below, by the posterior border of the horizontal part of the palatine bone; laterally, by the medial pterygoid lamina; they are separated from each other by the posterior border of the vomer.

DIFFERENCES IN THE SKULL DUE TO AGE

At birth the skull is large in proportion to the other parts of the skeleton, but the base is short and narrow in proportion to the vault; the facial portion is small and equals only about one-eighth of the bulk of the cranium as compared with one-half in the adult. The frontal and parietal tuberosities or eminences are prominent, and when the skull is viewed from above it presents a pentagonal outline with its

FIG. 356.—Skull at birth, showing frontal and occipital fonticuli.



greatest width at the parietal tuberosities; on the other hand, the glabella, superciliary arches, and mastoid processes are not developed. Ossification of the skull bones is not completed, and many of them—e.g. the occipital, temporals, sphenoidal, frontal, and mandible—consist of more than one piece. Unossified membranous intervals, termed fonticuli (fontanelles), are seen at the angles of the parietal bones; these fonticuli are six in number: two, the frontal and occipital, are situated in the middle line, and two, the sphenoidal and mastoid, on either side.

The *frontal* or *anterior fonticulus* (fig. 356) is the largest, and is placed at the junction of the sagittal, coronal, and frontal sutures; it is lozenge-shaped, and measures about 4 cm. in its anteroposterior and 2.5 cm. in its transverse diameter. The *occipital* or *posterior fonticulus* (fig. 356) is triangular in form and is situated at the junction of the sagittal and lambdoidal sutures.

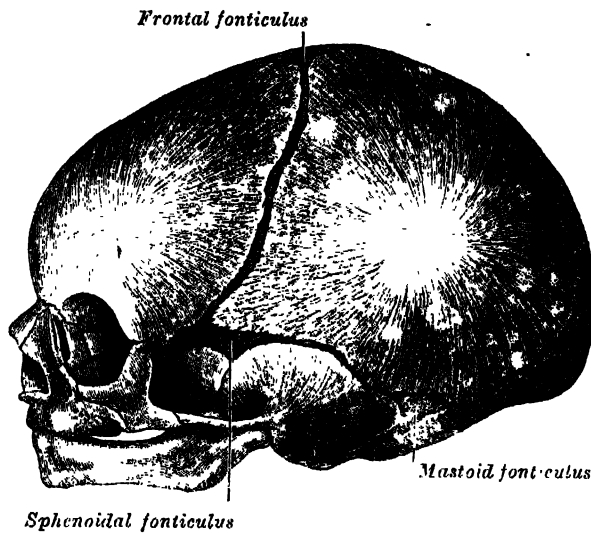
The *sphenoidal* and *mastoid fonticuli* (fig. 357) are small, irregular in shape, and correspond respectively with the sphenoidal and mastoid angles of the parietal bones. An additional fonticulus is sometimes seen in the sagittal suture at the region of the obelion.

The fonticuli are usually closed by the growth and extension of the bones which surround them, but sometimes they are the sites of separate ossific centres which develop into sutural bones. The occipital and sphenoidal fonticuli are obliterated within two or three months after birth; the mastoid fonticulus is usually closed about the end of the first year, and the frontal, about the middle of the second year.

The smallness of the face at birth is mainly accounted for by the rudimentary condition of the maxillæ and mandible, the non-eruption of the teeth, and the small size of the maxillary air-sinuses and nasal cavities. At birth the nasal cavities lie almost entirely between the orbits, and the lower border of the anterior nasal aperture is only a little below the level of the orbital floor. With the eruption of the deciduous teeth there is an enlargement of the face and jaws, and these changes are still more marked after the second dentition.

The skull grows rapidly from birth to the seventh year, by which time the lamina cribrosa of the ethmoidal bone, the foramen magnum, and the petrous parts of the temporal bones have reached their full size, and the orbital cavities are only a little smaller than those of the adult. Growth is slow from the seventh year

FIG. 357.—Skull at birth, showing sphenoidal and mastoid fonticuli.



until the approach of puberty, when a second period of activity occurs : this results in an increase in all directions, but it is especially marked in the frontal and facial regions, where it is associated with the development of the air-sinuses.

Obliteration of the sutures of the vault of the skull takes place as age advances. It may commence between the ages of thirty and forty on the inner surface, and about ten years later on the outer surface of the skull ; the dates given are, however, only approximate, as it is impossible to state with anything like accuracy the time at which the sutures are closed. Obliteration usually occurs first in the lower part of the coronal suture, next in the posterior part of the sagittal, and then in the lambdoidal.

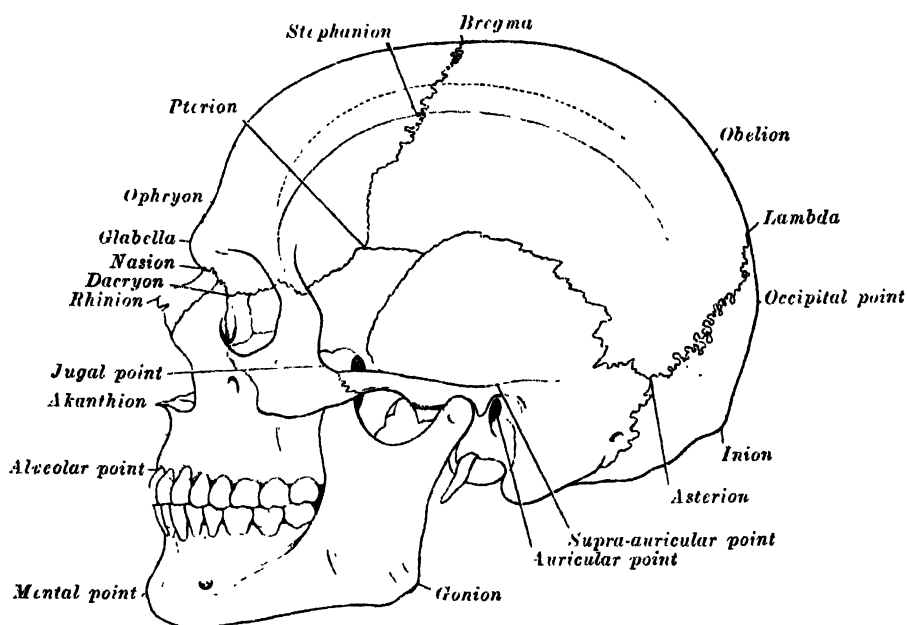
In old age the skull generally becomes thinner and lighter, but in a small proportion of cases it increases in thickness and weight. The most striking feature of the old skull is the diminution in the size of the maxillæ and mandible consequent on the loss of the teeth and the absorption of the alveolar processes. This is associated with a marked reduction in the vertical measurement of the face and with an alteration in the angles of the mandible.

SEX DIFFERENCES IN THE SKULL.

Until the age of puberty there is little difference between the skull of the female and that of the male. The skull of an adult female is as a rule lighter and smaller, and its capacity about 10 per cent. less, than that of the male. Its walls are thinner and its muscular ridges less strongly marked ; the glabella, superciliary arches, and mastoid processes are less prominent and the corresponding air-sinuses are small or rudimentary. The upper margin of the orbit is sharp, the forehead vertical,

the frontal and parietal tuberosities prominent, and the vault somewhat flattened. The contour of the face is more rounded, the facial bones are smoother, and the maxillæ and mandible and their contained teeth smaller. From what has been said it will be seen that more of the infantile characteristics are retained in the skull of the adult female than in that of the adult male. A well-marked male or female skull can easily be recognised as such, but in some cases the respective characteristics are so indistinct that the determination of the sex may be difficult or impossible.

FIG. 358.—Outline of side view of skull.



CRANIOLOGY

Skulls vary in size and shape, and the term craniology is applied to the study of these variations.

The capacity of the cranial cavity constitutes a good index of the size of the brain which it contained, and is most conveniently arrived at by filling the cavity with shot and measuring the contents in a graduated vessel. Skulls may be classified according to their capacities as follows:

1. *Microcephalic*, with a capacity of less than 1350 c.cm.—e.g. those of native Australians and Andaman Islanders.
2. *Mesocephalic*, with a capacity of from 1350 c.cm. to 1450 c.cm.—e.g. those of African negroes and Chinese.
3. *Megacephalic*, with a capacity of over 1450 c.cm.—e.g. those of Europeans, Japanese and Eskimos.

In comparing the shape of one skull with that of another it is necessary to adopt some definite position in which the skulls should be placed during the process of examination. They should be so placed that a line carried through the lower margin of the orbit and upper margin of the opening of the external acoustic meatus is in the horizontal plane. The normæ of one skull can then be compared with those of another, and the differences in contour and surface-form noted. Further, it is necessary that the various linear measurements used to determine the shape of the skull should be made between definite and easily localised points on its surface. The principal points may be divided into two groups: (1) those in the median plane, and (2) those on either side of it (fig. 358).

The points in the median plane are the:

Mental point. The most prominent point of the chin.

Alveolar point or prosthion. The central point of the anterior margin of the upper alveolar arch.

Akanthion. The tip of the anterior nasal spine.

Subnasal point. The middle of the lower border of the anterior nasal aperture, at the base of the anterior nasal spine.

Rhinion. The most prominent point of the internasal suture.

Nasion. The central point of the frontonasal suture.

Glabella. The point in the middle line at the level of the superciliary arches.

Ophryon. The point in the middle line of the forehead at the level where the temporal lines most nearly approach each other.

Bregma. The meeting point of the coronal and sagittal sutures.

Obelion. A point in the sagittal suture on a level with the parietal foramina.

Lambda. The point of junction of the sagittal and lambdoidal sutures.

Occipital point. The point in the middle line of the occipital bone farthest from the glabella.

Inion. The external occipital protuberance.

Opisthion. The mid-point of the posterior margin of the foramen magnum.

Basion. The mid-point of the anterior margin of the foramen magnum.

The points on either side of the median plane are the :

Gonion. The outer margin of the angle of the mandible.

Jugal point. The angle between the temporal border of the zygomatic bone and the upper border of the zygomatic arch.

Dacryon. The point of union of the anterosuperior angle of the lacrimal with the frontal bone and the frontal process of the maxilla.

Pterion. The point where the great wing of the sphenoidal bone joins the sphenoidal angle of the parietal.

Stephanion. The point where the temporal line intersects the coronal suture.

Auricular point. The centre of the orifice of the external acoustic meatus.

Supra-auricular point. A point on the posterior root of the zygoma, above the middle of the orifice of the external acoustic meatus.

Asterion. The point of meeting of the lambdoidal, masto-occipital, and mastoparietal sutures.

The *horizontal circumference* of the cranium is measured in a plane passing through the glabella in front, and the occipital point behind. It averages about 50 cm. in the female and 52.5 cm. in the male.

The *occipitofrontal* or *longitudinal arc* is measured from the basion over the middle line of the vertex to the opisthion, while the *basinasal length* is the distance between the basion and the nasion. These two measurements, plus the antero-posterior diameter of the foramen magnum, represent the *vertical circumference* of the cranium.

The *length* is measured from the glabella to the occipital point, while the *breadth* or greatest transverse diameter is usually found a little above and behind the opening of the external acoustic meatus. The proportion of breadth to length $\frac{\text{breadth} \times 100}{\text{length}}$ is termed the *cephalic index* or *index of breadth*.

The *height* is measured from the basion to the bregma, and the proportion of height to length $\frac{\text{height} \times 100}{\text{length}}$ constitutes the *vertical* or *height index*.

In studying the face the principal points to be noticed are the proportion of its length to its breadth, the shape of the orbits and of the anterior nasal aperture, and the degree of projection of the jaws.

The *length of the face* is measured from the nasion to the chin, or, if the mandible be wanting, to the alveolar point; its *width* is the distance between the zygomatic arches. By comparing the length with the width of the face, skulls may be divided into two groups; *dolichofacial* (long-faced) and *brachyfacial* (short-faced).

The *orbital index* signifies the proportion which the orbital height bears to the orbital width, thus :

$$\frac{\text{orbital height} \times 100}{\text{orbital width}}$$

The *nasal index* expresses the proportion which the width of the anterior nasal aperture bears to the height of the nose, the latter being measured from the nasion to the lower margin of the nasal aperture, thus :

$$\frac{\text{nasal width} \times 100}{\text{nasal height}}$$

The degree of projection of the jaws is determined by the *gnathic* or *alveolar index*, which represents the proportion between the basi-alveolar and basinasal lengths, thus :

$$\frac{\text{basi-alveolar length} \times 100}{\text{basinasal length}}$$

The *dental index* is arrived at by comparing the *dental length* (i.e. the distance between the anterior surface of the first premolar and the posterior surface of the third molar tooth of the maxilla) with the basinasal length, thus :

$$\frac{\text{dental length} \times 100}{\text{basinasal length}}$$

The following table, modified from that given by Duckworth,* illustrates how some of these indices may be utilised in the classification of skulls :

INDEX.	CLASSIFICATION.	NOMENCLATURE.	EXAMPLES.
1. Cephalic .	Below 75	Dolichocephalic	Kaffirs and Native Australians
	Between 75 and 80 .	Mesaticephalic .	Europeans and Chinese
	Above 80	Brachycephalic .	Mongolians and Andamans
2. Orbital .	Below 84	Microseme . . .	Tasmanians and Native Australians
	Between 84 and 89 .	Mesoseme . . .	Europeans .
	Above 89	Megaseme . . .	Chinese and Polynesians
3. Nasal . .	Below 48	Leptorhine . . .	Europeans
	Between 48 and 53 .	Mesorhine . . .	Japanese and Chinese
	Above 53	Platyrrhine . . .	Negroes and Native Australians
4. Gnathic .	Below 98	Orthognathous .	Europeans
	Between 98 and 103 .	Mesognathous .	Chinese and Japanese
	Above 103	Prognathous . .	Native Australians

Applied Anatomy.—Occasionally a protrusion of the brain or its membranes may take place through one of the sutures, owing to non-closure. When the protrusion consists of membranes only, and is filled with cerebrospinal fluid, it is called a *meningocele*; when it consists of brain as well as membranes, it is termed an *encephalocele*. These malformations are usually found in the middle line, and most frequently at the back of the head, the protrusion taking place between the centres of ossification of the occipital squama (see p. 196). They generally occur through the upper part of the vertical fissure, which is the last to close, but not uncommonly through the lower part, when the foramen magnum may be incomplete. More rarely these protrusions are met with in other situations, as in the sagittal, lambdoidal, and other sutures, or through abnormal gaps at the sides or base of the skull.

The chief function of the skull is to protect the brain, and therefore those portions of the skull which are most exposed to external violence are thicker than those which are shielded from injury by overlying muscles. Thus, the skull-cap is thick and dense, whereas the temporal squamæ, being protected by the Temporales muscles, and the inferior occipital fossæ, being shielded by the muscles at the back of the neck, are thin and fragile. Fracture of the skull is further prevented by its elasticity, its rounded shape, and its construction of a number of secondary elastic arches, each made up of a single bone. The manner in which vibrations are transmitted through the bones of the skull is also of importance as regards its protective mechanism, at all events as far as the base is concerned. In the vault, the bones being of a fairly equal thickness and density, vibrations are transmitted in a uniform manner in all directions, but in the base owing to the varying thickness and density of the bones, this is not so; and therefore in this situation there are special buttresses which serve to carry the vibrations in certain definite directions. At the front of the skull, on either side, is the ridge which separates the anterior from the middle fossa of the base; and behind, the ridge or buttress which separates the middle from the posterior fossa; and if any violence is applied to the vault, the vibrations would be carried along these buttresses to the sella turcica, where they meet. This part has been termed the 'centre of resistance,' and here there is a special protective mechanism to guard the brain. The subarachnoid cavity at the base of the brain is dilated, and the cerebrospinal fluid which fills it acts as a water-cushion to shield the brain from injury. In like manner, when violence is applied to the base of the skull, as in falls upon the feet, the vibrations are carried backwards through the occipital crest, and forwards through the basilar part of the occipital and body of the sphenoid to the vault of the skull.

* W. L. H. Duckworth, *Morphology and Anthropology*, Cambridge University Press.

Fractures of the skull are best considered as affecting either the vault or the base. Fractures of the vault generally involve the whole thickness of the bone; but sometimes the inner table alone is fractured, and portions of it driven inwards. As a rule, in fracture of the skull, the inner table is more splintered and comminuted than the outer, and this is due to several causes. It is thinner and more brittle; the force of the violence as it passes inwards becomes broken up, and is more diffused by the time it reaches the inner table; the bone being in the form of an arch bends as a whole and spreads out, and thus presses the particles together on the convex surface of the arch, i.e. the outer table, and forces them asunder on the concave surface or inner table; and, lastly, there is nothing firm under the inner table to support it and oppose the force. Fractures of the vault may be either simple, or starred and comminuted, and the fragments may be depressed or elevated. Cases of fracture with elevation of the fractured portion are uncommon, and can only be produced by direct wound. In comminuted fracture, a portion of the skull is broken into several pieces, the lines of fracture radiating from a centre where the chief impact of the blow was felt; if the fracture is also depressed, a fissure circumscribes the radiating lines, enclosing a portion of the skull. If this area is circular it is termed a 'pond' fracture, and has probably been caused by a round instrument, as a life-preserver or hammer; if elliptical in shape it is termed a 'gutter' fracture, and owes its shape to the instrument which has produced it, as a poker. Fracture of the outer table alone may occur in the region of the frontal air-sinuses where the two tables are completely separated.

Fractures of the base of the skull may be produced by *indirect* or *direct* violence.

I. In cases of the former class the violence is applied to the vertex or some part of the cranial convexity, as when a person falls from a height on to his head and a fracture of the base results. The mechanism of this form of fracture was formerly explained by the doctrine of *contrecoup*, i.e. that the force was transmitted from one side of the skull to the other; but this view is no longer held, and there are at the present day two theories as to the mode of causation of these fractures. (a) According to Arakeli's theory of *irradiation* all fractures of the base are produced by a fissure, which starts from the point of injury and radiates to the base. There can be little doubt that many cases of fracture of the base, especially of the middle fossæ, are caused in this way, but it is insufficient to explain all, since instances have been met with of fracture of the base of the skull in which there has been no fracture of the vault. (b) To explain these cases, another theory, known as the *compression* or *bursting* theory, has been suggested. If a hollow, elastic sphere is compressed from above downwards, it will bulge laterally, and, if the compression is sufficient, it will eventually burst in the situation where it bulges. Now, the skull is an elastic sphere, and when compression is applied to it, its diameter will be reduced along the line of greatest pressure and will therefore be increased in other directions, and may increase to such an extent that bursting occurs. In a hollow elastic sphere of uniform thickness, the bulging and subsequent bursting take place at the equatorial line midway between the two points of compression; but the skull is not of uniform thickness, and therefore the bulging and subsequent bursting take place at the weakest part.

II. Direct violence may be applied to the base of the skull in several different ways: by the impact of the vertebral column against the condyles of the occipital bone, in falls on the buttocks or feet; by the condyle of the mandible being driven against the mandibular fossa, in blows or falls on the chin; by the thrusting of a pointed instrument through the orbit or nose; by gunshot wounds through the mouth; and by a fall or a stab on the back of the head.

In the majority of cases the fracture is compound. The most common place for fracture of the base to occur is through the middle fossa, and here the fissure usually takes a fairly definite course. Starting from the point struck, which is generally somewhere in the neighbourhood of the parietal eminence, it runs downwards through the parietal and the temporal squama and across the petrous portion, frequently traversing and implicating the internal acoustic meatus, to the foramen lacerum. From this it may pass across the body of the sphenoid, through the sella turcica, to the foramen lacerum of the other side, and may indeed travel round the whole cranium so as completely to separate the anterior from the posterior part. The course of the fracture explains the symptoms to which fracture in this region may give rise: thus if the fissure pass across the internal acoustic meatus injury to the facial and acoustic nerves may result, with consequent facial paralysis and deafness; or the tubular prolongation of the arachnoid around these nerves in the meatus may be torn and thus permit of the escape of the cerebrospinal fluid should there be a communication between the internal ear and the tympanic cavity together with rupture of the tympanic membrane, as is frequently the case; again, if the fissure pass across the sella turcica and the mucoperiosteum covering the under surface of the body of the sphenoid is torn, blood will find its way into the pharynx and be swallowed, and after a time vomiting of blood will result. Fractures of the anterior fossa, involving the bones forming the roof of the orbit and nasal cavity, are generally the result of blows on the forehead; but fracture of the lamina cribrosa of the ethmoid may be a complication of fracture of the nasal bone. When the fracture implicates the roof of the orbit, the blood finds its way into this cavity, and, travelling forwards, appears as a subconjunctival ecchymosis. If the roof of the nasal cavity be fractured, the blood escapes from the nose.

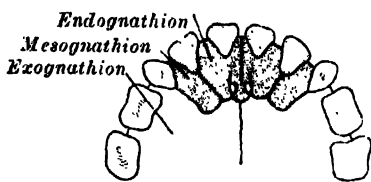
In rare cases there may be also escape of cerebrospinal fluid from the nose should the dura mater and arachnoid have been torn. In fractures of the posterior fossa, extravasation of blood may appear at the nape of the neck, beneath the muscles attached to the superior nuchal line of the occipital bone.

Deformities of the skull.—Local deformities of the skull are not rare in syphilis, taking the form of gummas which not infrequently break down and suppurate, and of periosteal thickenings which are known as *Parrot's nodes* when they occur around the coronal and sagittal sutures in infants. General enlargement of the skull, producing characteristic deformities of various types, occurs in certain rare diseases such as otitis deformans, acromegaly, and leontiasis ossea; it also is present in the much commoner disorders, rickets and hydrocephalus. In rickety cases the skull becomes enlarged from the formation of periosteal outgrowths of soft tissue on the outer side of the skull. These deposits are very rich in blood-vessels, and occur between the ridges of the cranial bones and their centres of ossification, and are symmetrically arranged—often about the anterior fontanelle. The anterior fontanelle itself, instead of closing between the 18th and 24th months, as it normally does, remains patent in rickets until the third or even the sixth year. The general shape of the skull alters. The forehead is high and square, with prominent frontal eminences, and the head tends to be cubical or box-shaped: the enlargement of the head in rickets appears to be greater than it really is because the development of the facial bones is retarded. The base of the nose may appear sunken, from retarded development of the basis cranii. In marked cases of rickets these changes in the shape of the skull are permanent. In congenital hydrocephalus, or enlargement of the head due to the presence of excess of fluid in the ventricles of the brain, the cranium becomes globular, and its bones are thin and often widely separated.

The tympanic antrum, situated in the mastoid portion of the temporal bone, is often the seat of suppuration as a result of infection extending backwards from the tympanic cavity. In such cases, the surgeon has to open the antrum in order to give exit to the pus; this he does by introducing his gouge in the supramental triangle (see p. 203). A line is drawn horizontally through the upper border of the bony external acoustic meatus, and a second vertically through the posterior wall of the meatus, and the gouge is applied in the angle where these two lines intersect; if the instrument be introduced at a higher level it will open the middle fossa of the skull. It is to be carried in the direction of the external acoustic meatus—inwards, forwards, and a little upwards—for a distance of from 1 to 1.5 cm., when the antrum will be reached. In some cases of middle-ear trouble, septic thrombosis of the transverse sinus takes place, and it becomes necessary to work backwards and explore the sinus.

In connexion with the bones of the face a common malformation is *cleft palate*. The cleft usually starts posteriorly, and its most elementary form is a bifid uvula; or the cleft may extend through the soft palate; or the posterior part of the whole of the hard palate may be involved, the cleft extending as far forwards as the incisive foramen. In the

FIG. 359.—The premaxilla and its sutures (after Albrecht).



severest forms, the cleft extends through the alveolus and passes between the incisive or premaxillary bone and the rest of the maxilla; that is to say, between the lateral incisor and canine teeth. In some instances, the cleft runs between the central and lateral incisor teeth: and this has induced some anatomists to believe that the premaxillary bone is developed from two centres (fig. 359) and not from one, as was stated on p. 229. The medial segment, bearing a central incisor, is called an *endognathion*; the lateral segment, bearing the lateral incisor, is called a *mesognathion*. The cleft may affect one or both

sides; if the latter, the central part is frequently displaced forwards and remains united to the septum of the nose, the deficiency being complicated with a cleft in the lip (hare-lip). On examining a cleft palate in which the alveolus is not implicated, the cleft will generally appear to be in the median line, but occasionally is unilateral and in some cases bilateral. To understand this it must be borne in mind that three processes are concerned in the formation of the palate—the palatine processes of the two maxillæ, which grow in horizontally and unite in the middle line; and the ethmiovomerine process, which grows downwards from the base of the skull and frontonasal process to unite with the palatine processes in the middle line. In those cases where the palatine processes fail to unite with each other and with the median process, the cleft of the palate is median; where one palatine process unites with the median septum, the other failing to do so, the cleft in the palate is unilateral. In some cases where the palatine processes fail to meet in the middle, the ethmiovomerine process grows downwards between them and thus produces a bilateral cleft. Occasionally there may be a hole in the middle line of the hard palate, the anterior part of the hard and the soft palate being perfect; this is rare, because, as a rule, the union of the various processes progresses from before backwards, and therefore the posterior part of the palate is more frequently defective than the anterior.

The bones of the face are sometimes fractured as the result of direct violence. Those most commonly broken are the nasal bones and the mandible; the latter is by far the most frequently fractured of all the facial bones. Fracture of the *nasal bone* is for the most part transverse, and takes place about 1.25 cm. from the free margin. The broken portion may be displaced backwards or more generally to one side by the force which produced the lesion. The *zygomatic bone* is probably never broken alone—that is to say, without fracture of some of the other bones of the face. The *zygomatic arch* is occasionally fractured, and when this occurs as a result of direct violence the fragments may be displaced inwards. Fractures of the *maxilla* may vary much in degree, from the chipping off of a portion of the alveolar arch to an extensive comminution of the whole bone from severe violence, as the kick of a horse. The most common situation for a fracture of the *mandible* is in the neighbourhood of the canine tooth, as at this spot the bone is weakened by the deep socket for the root of this tooth; it is next most frequently fractured at the angle; then at the symphysis; and finally the neck of the condyle or the coronoid process may be broken. Occasionally a double fracture may occur, one in either half of the bone. The fractures are usually compound, from laceration of the mucous membrane covering the gums. Displacement readily occurs and is difficult to rectify: it results in inequality in the line of the teeth and is commonly due to the muscles attached in the region of the symphysis dragging this portion downwards.

Necrosis of dental origin, or as the result of syphilis, is of frequent occurrence in the maxilla or the mandible: it may also occur as the result of fumes of phosphorus in persons engaged in the manufacture of matches. In the maxilla cysts occur in the antrum. In either jaw they occur in connexion with the teeth, those associated with unerupted teeth being called *dentigerous cysts*, and those in connexion with the stumps of diseased teeth, *dental cysts*. Tumours, innocent or malignant, originate in either jaw. The results of distention of the walls of the maxillary antrum by fluid or growth are given on p. 227.

In the operation of excision of the maxilla, the central incisor tooth having been extracted, the incision is begun just below the medial canthus of the eye and passes along the side of the nose round the ala and down the middle line of the upper lip into the mouth. A second incision is made from the commencement of the first along the lower border of the orbit as far as the prominence of the zygomatic bone. The flap thus formed is reflected, so as to expose the bone. The periosteum attached along the lower margin of the orbit is now to be incised, and the periosteum covering the floor of the orbit is raised from the bone, for in all cases it is essential that this mucous layer should not be removed. The mouth is now widely opened with a gag, and the mucous membrane covering the hard palate incised down to the bone in the middle line, and the soft palate separated from the hard. The surgeon having first separated the ala of the nose from its bony attachment, proceeds to divide the connexions of the bone with the other bones of the face. They are (1) the junction with the zygomatic bone, the line of section being carried into the inferior orbital fissure; (2) the frontal process of the maxilla; a small portion of its upper extremity, connected with the nasal bone in front, the lacrimal bone behind, and the frontal bone above, being left; (3) the connexion with the opposite maxilla and with the palatine, are broken through. The bone is now firmly grasped and the remaining attachments of the orbital plate with the ethmoid, and of the back of the bone with the palatine, are broken through. Occasionally, in removing the maxilla, it will be found that the orbital plate can be saved, and this should always be done if possible. A horizontal saw-cut should then be made just below the intraorbital foramen.

THE EXTREMITIES

The extremities or limbs are four in number: a *superior pair*, subservient mainly to prehension; and an *inferior pair*, intended for support and locomotion. Both pairs are constructed after a common type, but certain functional differences are observed between them.

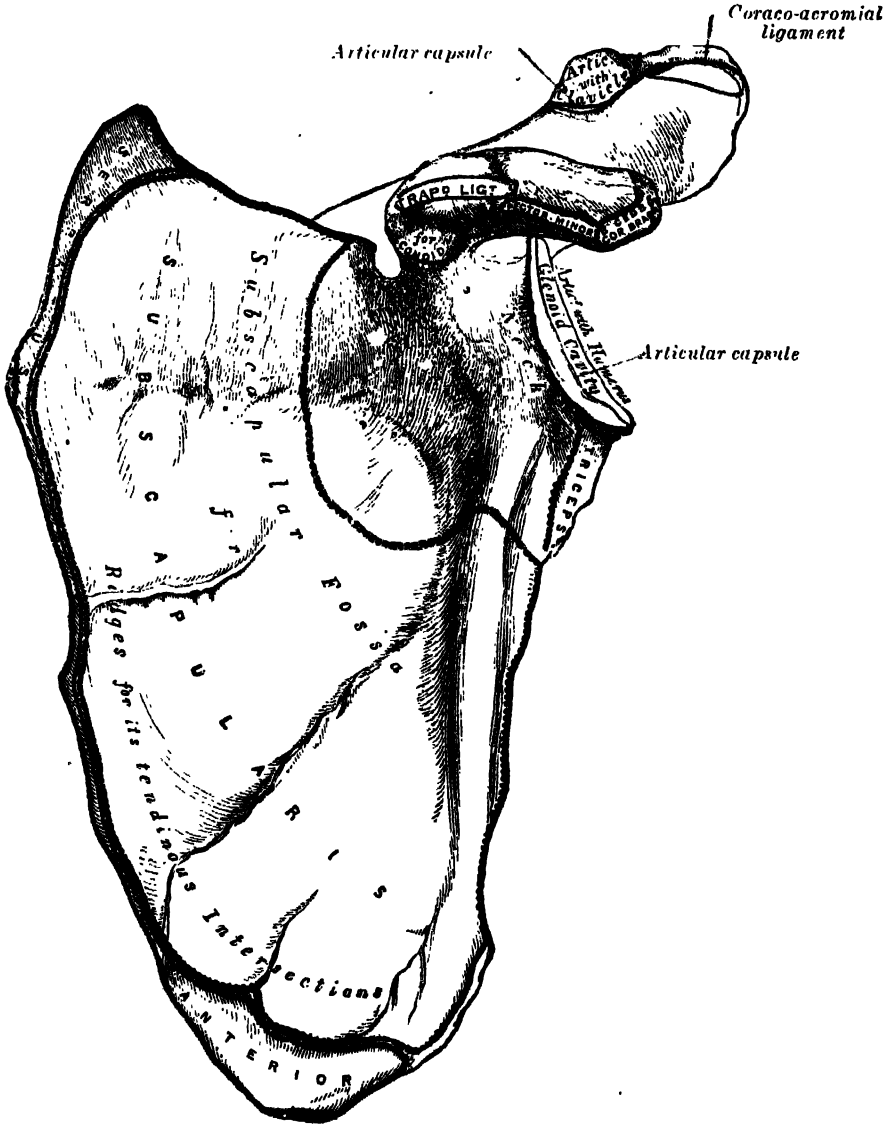
The bones by which the upper and lower limbs are attached to the trunk constitute respectively the shoulder and pelvic girdles. The *shoulder girdle* or *girdle of the superior extremities* is formed by the scapulæ and clavicles, and is imperfect in front and behind. In front, however, it is completed by the upper end of the sternum, with which the medial ends of the clavicles articulate. Behind, it is widely imperfect, the scapulæ being connected to the trunk by muscles only. The *pelvic girdle* or *girdle of the inferior extremities* is formed by the hip-bones which articulate with each other in front at the symphysis pubis. It is imperfect behind, but the gap is filled by the upper part of the sacrum. The pelvic girdle, with the sacrum, is a complete ring, massive and comparatively rigid, in marked contrast to the lightness and mobility of the shoulder girdle.

BONES OF THE SUPERIOR EXTREMITY

THE SCAPULA

The **scapula** or shoulder-blade is a flat, triangular bone, with two surfaces, three borders, and three angles.

FIG. 360.—Left scapula. Costal surface.

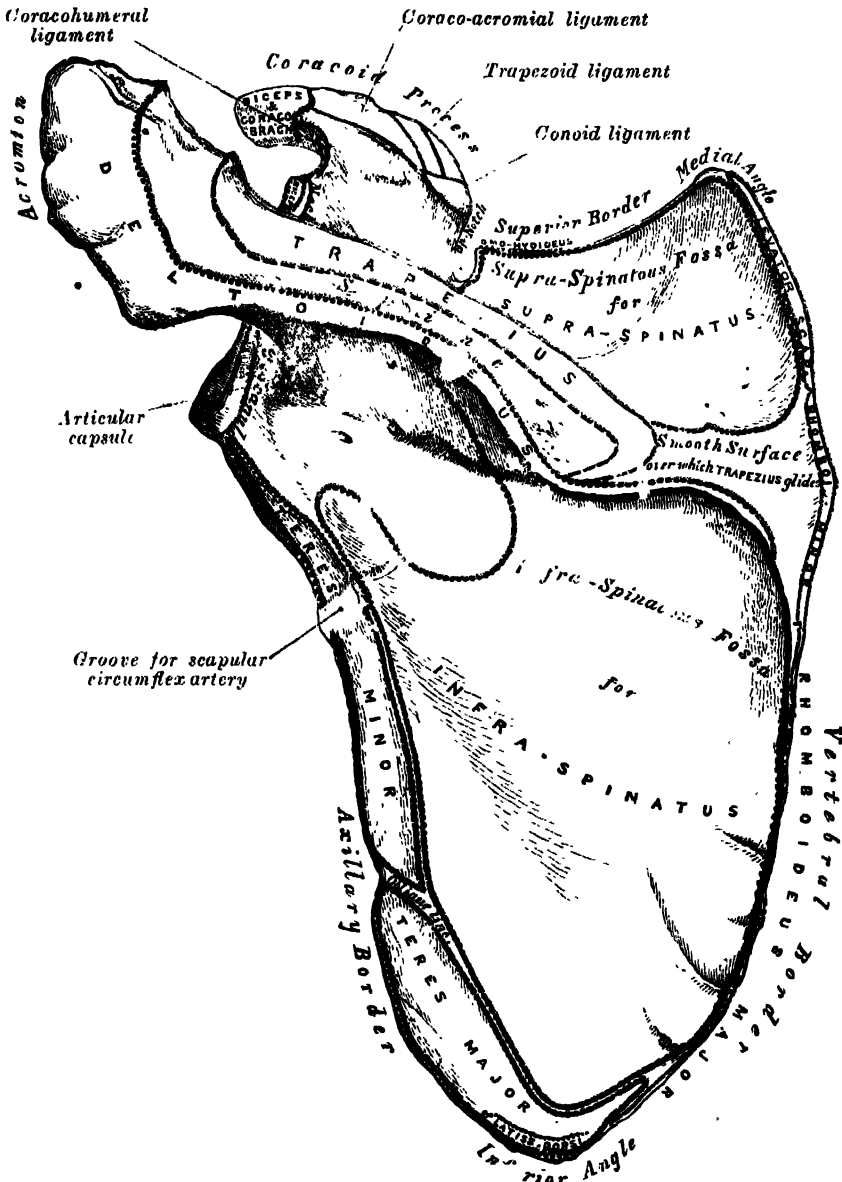


The *costal surface* (fig. 360) presents a broad cavity, the *subscapular fossa*. The medial two-thirds of the fossa are marked by several oblique ridges, which run lateralwards and upwards. The ridges give attachment to the tendinous intersections, and the surfaces between them to the fleshy fibres, of the *Subscapularis*; the lateral third of the fossa is covered by this muscle. The fossa is separated from the vertebral border by smooth triangular areas at the medial and inferior angles of the bone, and in the interval between the angles by a narrow ridge; these triangular areas and the intervening ridge

afford attachment to the *Serratus anterior*. At the upper part of the fossa the bone is bent on itself along a line corresponding with the attached margin of the spine.

The *dorsal surface* (fig. 361) is arched from above downwards, and is subdivided into two fossæ by a projecting plate of bone, the *spine*; the portion

FIG. 361.—Left scapula. Dorsal surface.



above the spine is called the *supraspinatus fossa*, and that below it the *infraspinatus fossa*. The *supraspinatus fossa* is concave and smooth; its medial two-thirds give origin to the *Supraspinatus*. The *infraspinatus fossa* is much larger than the preceding; towards its vertebral margin a shallow concavity is present at its upper part; the central part is convex, while that near the axillary border is deeply grooved. From the medial two-thirds of the fossa the *Infraspinatus* takes origin; the lateral third is covered by this muscle.

From the lower part of the glenoid cavity an elevated ridge runs downwards and backwards to the vertebral border, about 2.5 cm. above the inferior angle; it gives attachment to a fibrous septum which separates the Infraspinatus from the Teres major and Teres minor. The upper part of the surface between the ridge and the axillary border is narrow; it gives origin to the Teres minor, and is crossed by a groove for the passage of the scapular circumflex vessels. The lower part is somewhat triangular; it gives origin to the Teres major, and over it the *Latissimus dorsi* glides; frequently the latter muscle takes origin by a few fibres from this part of the bone. The two parts are separated by an oblique line which runs downwards and backwards from the axillary border; a fibrous septum is attached to this oblique line, and separates the Teres muscles from each other.

The *spine* is a triangular plate of bone, which crosses obliquely the medial four-fifths of the dorsal surface of the scapula at its upper part, and separates the supra- from the infraspinatus fossa. It begins at the vertebral border by a smooth, triangular area over which the tendon of insertion of the lower part of the *Trapezius* glides, and, gradually becoming more elevated, ends in the acromion, which overhangs the shoulder-joint. It is flattened from above downwards, and its apex is directed towards the vertebral border. It has two surfaces and three borders. Its *superior surface* forms a part of the supraspinatus fossa, and gives origin to a portion of the Supraspinatus. Its *inferior surface* forms part of the infraspinatus fossa, gives origin to a portion of the Infraspinatus, and presents near its centre the orifice of a nutrient canal. The *anterior border* is attached to the dorsal surface of the bone. The *posterior border*, or *crest of the spine*, is broad, with two lips and an intervening rough surface. The *Trapezius* is attached to the lateral three-fourths of the superior lip, and a rough tubercle is generally seen on the medial portion of the crest for the tendon of insertion of the lower part of this muscle; the *Deltoides* is attached to the whole length of the inferior lip; the area between the lips is subcutaneous and partly covered by the tendinous fibres of these muscles. The *lateral border* or *base*, the shortest of the three, is thick and slightly concave; it is continuous above with the under surface of the acromion, below with the posterior surface of the neck of the scapula. It forms the medial boundary of the *great scapular notch*, which connects the supra- and infraspinatus fossæ.

The *acromion* is a large triangular or oblong process which projects at first lateralwards from the spine, and then curves forwards and upwards, so as to overhang the glenoid cavity. Its *superior surface*, directed upwards, and slightly backwards and lateralwards, is subcutaneous. Its *inferior surface* is smooth and concave. Its *lateral border* is thick and irregular, and presents three or four tubercles for the tendinous origins of the *Deltoides*. Its *medial border*, shorter than the lateral, is concave, gives attachment to a portion of the *Trapezius*, and presents near its anterior extremity a small, oval surface for articulation with the acromial end of the clavicle. Its *apex*, which corresponds to the point of meeting of the lateral and medial borders in front, is thin, and to it the *coraco-acromial ligament* is attached.

Of the three borders of the scapula, the *superior* is the shortest and thinnest; it is concave, and extends from the medial angle to the base of the coracoid process. At its lateral part is the *scapular notch*, formed partly by the base of the coracoid process. This notch is converted into a foramen by the *superior transverse scapular ligament*, and transmits the *suprascapular nerve*; sometimes the ligament is ossified. From the adjacent part of the superior border the *Omohyoideus* takes origin. The *axillary border* (fig. 362) is the thickest; it begins above at the lower margin of the glenoid cavity, and runs downwards and backwards to the inferior angle. Immediately below the glenoid cavity is a rough impression, the *infraglenoid tuberosity*, about 2.5 cm. in length, which gives origin to the long head of the *Triceps brachii*; in front of this a longitudinal groove extends as far as the lower third of this border, and affords origin to part of the *Subscapularis*. The inferior third is thin and serves for the attachment of a few fibres of the Teres major behind, and of the *Subscapularis* in front. The *vertebral border* is the longest and extends from the medial to the inferior angle; it is bent so that the portion above the spine forms an obtuse angle with the part below. It gives insertion to the *Llevator*

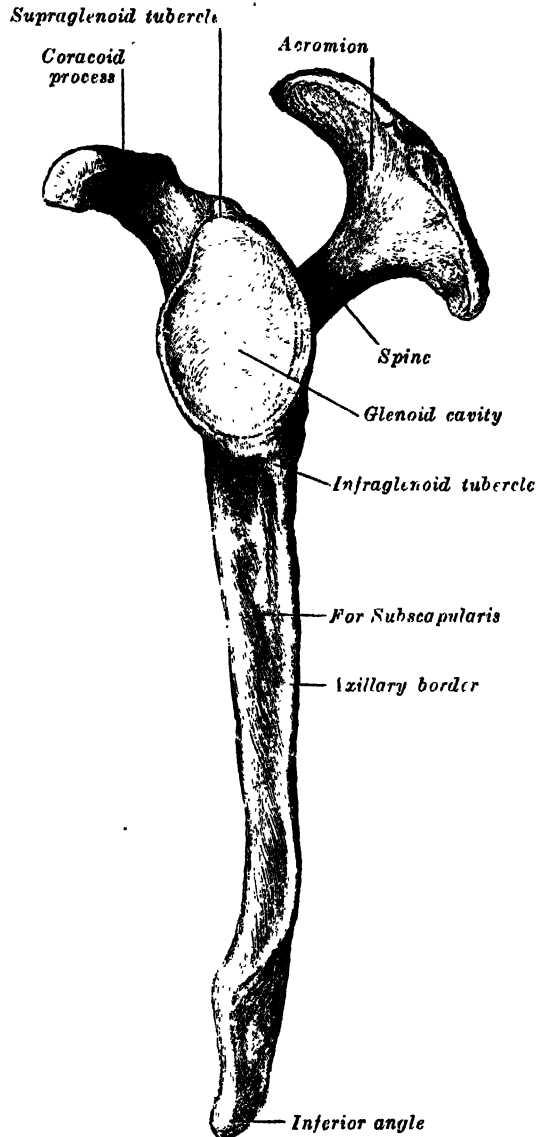
scapulæ above the triangular surface at the apex of the spine, to the Rhomboideus minor on the edge of that surface, and to the Rhomboideus major below it; the last muscle is usually attached by means of a fibrous arch, connected above to the lower part of the triangular surface at the apex of the spine, and below to the lower part of the border.

Of the three angles, the *medial*, at the junction of the superior and vertebral borders, is thin, smooth, and rounded; it gives attachment to a few fibres of the Levator scapulæ. The *inferior angle*, thick and rough, is formed by the union of the vertebral and axillary borders; its dorsal surface gives origin to the Teres major and frequently to a few fibres of the Latissimus dorsi. The *lateral angle* is the thickest part of the bone, and is sometimes called the *head of the scapula*. On it is a shallow pyriform, articular surface, the *glenoid cavity* (fig. 362), which looks lateralwards and forwards and articulates with the head of the humerus; it is broader below than above and its vertical diameter is the longer. To its margin is attached a fibrocartilaginous lip, the *glenoidal labrum*, which deepens the cavity. At its apex is a small elevation, the *supraglenoid tuberosity*, to which the long head of the Biceps brachii is attached.

The *neck* of the scapula (collum scapulæ) is the somewhat constricted part of the bone which immediately surrounds the glenoid cavity, and separates it superiorly from the base of the coracoid process; it is more distinctly marked below and behind than above and in front.

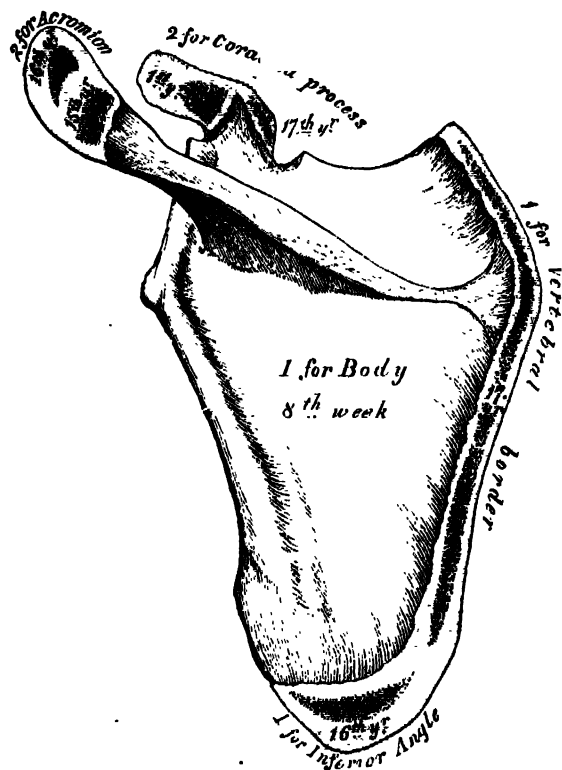
The *coracoid process* is a thick curved process attached by a broad base to the upper part of the head of the scapula; it runs at first upwards, forwards, and medialwards; then, becoming smaller, it changes its direction, and projects forwards and lateralwards. The ascending portion is flattened from before backwards, and presents in front a smooth concave surface, across which the Subscapularis passes. The horizontal portion is flattened from above downwards; its upper surface is convex and irregular, and gives attachment to the Pectoralis minor; its under surface is smooth; its medial and lateral borders are rough—the former gives attachment to the Pectoralis minor and the latter to the coraco-acromial ligament; the apex is embraced by the conjoined tendon of origin of the Coracobrachialis and short head of the Biceps.

FIG. 362.—Left scapula. Lateral view.



brachii, and gives attachment to the coracoclavicular fascia. On the medial part of the root of the coracoid process is a rough impression for the attachment of the conoid ligament; and running from it obliquely forwards and lateralwards, on to the upper surface of the horizontal portion, is an elevated ridge for the attachment of the trapezoid ligament.

FIG. 363.—Plan of ossification of the scapula. From seven centres.



Structure.—The head, processes, and thickened parts of the bone contain spongy substance; the rest consists of a thin layer of compact bone. The central part of the supraspinatous fossa and the greater part of the infraspinatous fossa are thin; occasionally the bone is found wanting in these situations, and the adjacent muscles are separated only by fibrous tissue.

Ossification (fig. 363).—The scapula is ossified from seven or more centres: one for the body, two for the coracoid process, two for the acromion, one for the vertebral border, and one for the inferior angle.

Ossification of the body begins in the eighth week of foetal life, and the centre spreads to form an irregular quadrilateral plate of bone, immediately behind the glenoid cavity. This plate extends so as to form the chief part of the bone, the spine growing up from its dorsal surface about the third month. At birth, the glenoid cavity, coracoid process, acromion, vertebral border, and inferior angle are cartilaginous. In the first year of life, ossification begins in the middle of the coracoid process, and this process joins the rest of the bone about the fifteenth year. Between the fourteenth and twentieth years, ossification of the remaining parts usually takes place in the following order; first, in the root of the coracoid process; secondly, near the base of the acromion; thirdly, in the inferior angle and contiguous part of the vertebral border; fourthly, near the extremity of the acromion; fifthly, in the vertebral border. The base of the acromion is formed by an extension from the spine; the two separate centres of the acromion unite, and then join with the extension from the spine. The upper third of the glenoid cavity is ossified from a subcoracoid centre, which appears between the tenth and eleventh and joins between the sixteenth and the eighteenth years. Further, an

epiphysial plate appears for the lower part of the glenoid cavity, while the tip of the coracoid process frequently presents a separate centre. These various epiphyses are joined to the bone by the twenty-fifth year. Failure of bony union between the acromion and spine sometimes occurs, the junction of these two parts being then effected by fibrous tissue, or by an imperfect articulation.

Applied Anatomy.—Fractures of the body of the scapula are rare, owing to the mobility of the bone, the thick layers of muscles by which it is encased, and the elasticity of the ribs on which it rests. Fracture of the neck is also uncommon. The most frequent course of a fracture is from the scapular notch to the infraglenoid tuberosity, and it derives its principal interest from its simulation of a subglenoid dislocation of the humerus. The diagnosis can be made by noting the alteration in the position of the coracoid process. The acromion is more frequently broken than any other part of the bone, and fibrous union is very liable to follow.

The presence of 'winged scapulae' (*scapulae alatae*) described in thin persons of feeble muscular development in whom the lower angles of the scapulae project unduly, is due partly to abnormal roundness of the thoracic wall ('barrel-shaped chest,' p. 192), and partly to weakness and flaccidity of the *Latissimus dorsi* and *Serratus anterior*. The shoulders are held low in these subjects, and the clavicles slope downwards and forwards, carrying with them the scapulae, which fit ill to the posterior wall of the chest and so tend to project from it.

Tumours of various kinds grow from the scapula. Of the innocent form probably the osteomata are the most common. When an osteoma grows from the costal surface of the scapula, as it sometimes does, it is of the compact variety, such as usually grows from membrane-formed bones, as the bones of the skull. Sarcomatous tumours sometimes grow from the scapula, and may necessitate removal of the bone, with or without amputation of the upper limb. The bone may be excised by a T-shaped incision, and the flaps being reflected, the removal is commenced from the vertebral border, so that the subscapular vessels which lie along the axillary border are among the last structures divided, and can be readily secured.

THE CLAVICLE (CLAVICULA)

The clavicle or collar-bone (figs. 364 and 365) articulates medially with the manubrium sterni, and laterally with the acromion of the scapula.* It is a long bone, and is placed nearly horizontally at the upper and anterior part of the thorax. It is curved somewhat like the italic letter *f*, presenting a double curvature, with a convexity forwards at the sternal end and a concavity forwards at the acromial end. Its lateral third is flattened, whilst its medial two-thirds are of a rounded or prismatic form.

The lateral third has two surfaces, an upper and a lower; and two borders, an anterior and a posterior. The *upper surface* is flat and rough: it affords attachment to the *Deltoides* in front, and the *Trapezius* behind: between these a small portion of the bone is subcutaneous. The *under surface* is flat; at its posterior border, near the junction of the prismatic and flattened portions of the bone, is a rough eminence, the *coracoid tuberosity* (conoid tubercle); this overlies the coracoid process of the scapula, and gives attachment to the *conoid ligament*. From this tuberosity, the *oblique* or *trapezoid ridge* runs forwards and lateralwards, and affords attachment to the *trapezoid ligament*. The *anterior border* is concave, thin, and rough, and gives origin to a portion of the *Deltoides*; at its medial part there is frequently a tubercle, the *deltoid tubercle*. The *posterior border*, convex, rough, and thicker than the anterior, gives insertion to a part of the *Trapezius*.

The medial two-thirds constitute the prismatic portion of the bone, which is marked by three borders, separating three surfaces. The *anterior border* is continuous with the anterior border of the flat portion. Its lateral part is smooth, and corresponds to the interval between the attachments of the *Pectoralis major* and *Deltoides*; its medial part forms the lower boundary of an elliptical surface for the attachment of the clavicular portion of the *Pectoralis major*. The *superior border* is continuous with the posterior border of the flat portion, and separates the anterior from the posterior surface. Smooth and

* The clavicle acts especially as a fulcrum to enable the muscles to give lateral motion to the arm. It is accordingly absent in those animals whose fore-limbs are used only for progression, but is present for the most part in animals whose anterior extremities are clawed and used for prehension, though in some of them—as, for instance, in a large number of the carnivora—it is merely a rudimentary bone suspended among the muscles, and not articulating with either the scapula or sternum.

rounded laterally, it becomes rough towards the medial third for the attachment of the Sternocleidomastoideus, and ends at the upper angle of the sternal extremity. The *subclavian* or *posterior border* separates the posterior from the inferior surface, and extends from the coracoid tuberosity to the costal tuberosity; it forms the posterior boundary of the groove for the Subclavius, and gives attachment to a layer of cervical fascia which envelops the Omohyoideus. The *anterior surface* is between the superior and anterior borders. Its lateral part looks upwards, and is continuous with the superior surface of the flattened portion; it is smooth, convex, and nearly subcutaneous, being covered only by the Platysma. Its medial part is divided by a narrow subcutaneous region into two areas; a lower, elliptical in form, and directed forwards, for the attachment of the Pectoralis major; and an upper, for the attachment of the Sternocleidomastoideus. The *posterior or cervical surface* is smooth,

FIG. 364.—Left clavicle. Superior surface.

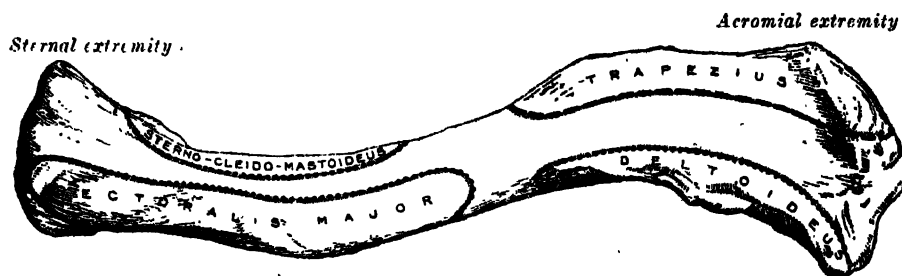
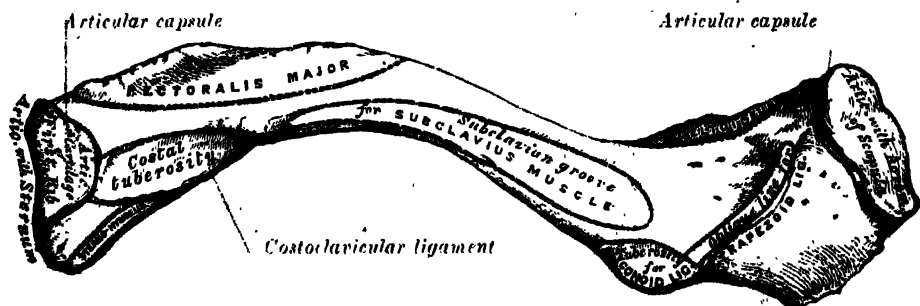


FIG. 365.—Left clavicle. Inferior surface.



and looks backwards towards the root of the neck. It is limited, above, by the superior border; below, by the subclavian border; medially, by the margin of the sternal extremity; and laterally, by the coracoid tuberosity. It is in relation with the transverse scapular vessels, and, at the junction of the curves of the bone, with the brachial plexus of nerves and the subclavian vessels. Near the sternal extremity, it gives attachment to part of the Sternohyoideus; and near its middle is a foramen directed lateralwards, which transmits a nutrient artery into the bone. A second nutrient foramen may be present on this, or on the inferior, surface. The *inferior or subclavian surface* is between the anterior and subclavian borders. It is narrow medially, but gradually increases in width laterally, and is continuous with the under surface of the flat portion. On its medial part is a rough area, the *costal tuberosity* (rhomboid impression), rather more than 2 cm. in length, for the attachment of the costoclavicular ligament. The rest of this surface is grooved, and gives insertion to the Subclavius muscle; the coracoclavicular fascia splits to enclose the muscle and is attached to the margins of the groove.

The *sternal extremity* of the clavicle is triangular in form, directed medialwards, and a little downwards and forwards; it presents an articular facet, concave from before backwards, convex from above downwards, which

articulates with the articular disc of the sternoclavicular joint. The lower part of the facet is continued on to the inferior surface of the bone as a small semi-oval area for articulation with the cartilage of the first rib. The circumference of the articular surface is rough for the attachment of ligaments; the upper angle and a narrow rough area below it give attachment to the articular disc.

The acromial extremity presents a small, flattened, oval surface directed slightly downwards, for articulation with the acromion of the scapula. The upper margin of the facet is rough for the attachment of the acromioclavicular ligament.

In the female, the clavicle is generally shorter, thinner, less curved, and smoother than in the male.* In the male the acromial end is on a level with, or slightly higher than, the sternal end; in the female the acromial end is a little below the level of the sternal end. In persons who perform considerable manual labour the clavicle becomes thicker and more curved, and its ridges for muscular attachment more prominently marked.

Structure.—The clavicle consists of spongy substance, enveloped by a layer of compact bone, which is much thicker in the intermediate part than at the extremities of the bone.

Ossification.—The clavicle begins to ossify before any other bone in the body: it is ossified from (a) two primary centres, a medial and a lateral, for the body,† which appear during the fifth or sixth week of foetal life and fuse about the forty-fifth day; and (b) a secondary centre for the sternal end, which appears about the eighteenth or twentieth year, and unites with the body of the bone about the twenty-fifth year.

In a 14 mm. embryo the future clavicle is represented by a band of connective tissue which extends from the acromion of the scapula to the tip of the first rib and is continuous with the rudiment of the sternum. In this band a medial and a lateral mass of 'precartilage' is developed, and in the adjacent ends of these masses the two centres for the body of the bone appear and soon fuse with each other. The sternal and acromial ends of the precartilaginous masses are converted into cartilage and into this the ossification of the body of the bone extends.

Applied Anatomy.—The clavicle is very frequently fractured, since it is much exposed to violence, and is the only bony connexion between the upper limb and the trunk, acting as a buttress to keep the point of the shoulder away from the thorax. It is, moreover, slender, and is very superficial. It may be broken by direct or indirect violence. The most common cause is, however, indirect violence, as the result of force applied to the hand or shoulder, and the bone then gives way at the junction of its lateral with its intermediate third, that is to say, at the junction of the two curves, for this is its weakest part. The fracture is generally oblique, and the displacement of the lateral fragment is downwards, forwards, and medialwards. The deformity is mainly due to the weight of the arm acting upon the fragment when the buttress-like action of the bone is gone, assisted by the muscles which pass from the thorax to the upper extremity. The medial fragment, as a rule, is little displaced. The main vessels of the upper limb and the great nerve-cords of the brachial plexus lie beneath the bone on the first rib and are liable to be wounded, especially in fracture from direct violence, when the force of the blow drives the broken ends inwards. Fortunately the Subclavius intervenes between these structures and the clavicle, and often protects them from injury.

The clavicle is occasionally the seat of sarcomatous tumours, rendering the operation of excision of the entire bone necessary. This is an operation of considerable difficulty and danger. It is best performed by exposing the bone freely, disarticulating at the acromial end, and turning it forwards. The removal of the lateral part is comparatively easy, but resection of the medial part is fraught with difficulty, the main danger being the risk of wounding the great veins which are in relation with its deep surface.

Great deformity of the clavicle may be met with in rickets, the natural curvatures of the bone being exaggerated until it takes an S shape, and 'green-stick' fracture is not uncommonly seen associated therewith.

* F. G. Parsons (*Journal of Anatomy and Physiology*, vol. li.) gives 153 mm. as the average length of the male clavicle, and 138 mm. as the average length of the female clavicle.

† Mall, *American Journal of Anatomy*, vol. v., 1900; Fawcett, *Journal of Anatomy and Physiology*, vol. xiv.

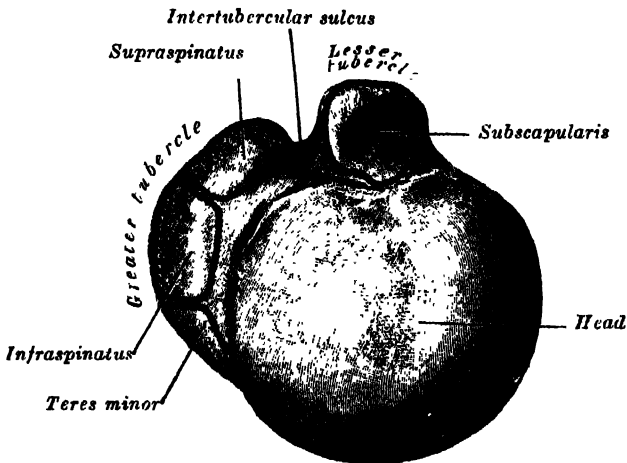
THE HUMERUS

The humerus (figs. 367 and 368), the longest and largest bone of the upper limb, is divisible into a body and two extremities.

The **upper extremity** consists of a large rounded *head* joined to the body by a constricted portion called the *neck*, and two eminences, the *greater* and *lesser tubercles*.

The **head** (fig. 366), nearly hemispherical in form, is directed upwards, medialwards, and a little backwards, it articulates with the glenoid cavity of the scapula. The circumference of its articular surface is slightly constricted, and is termed the *anatomical neck*, in contradistinction to a constriction below the tubercles called the *surgical neck* which is frequently the seat of fracture.

FIG. 366.—Head of left humerus, from above.



The *anatomical neck* forms an obtuse angle with the body and is best marked in the lower half of its circumference; in the upper half it is represented by a narrow groove separating the head from the tubercles. It affords attachment to the articular capsule of the shoulder-joint, and is perforated by numerous foramina for the transmission of blood-vessels.

The **greater tubercle** is situated laterally to the head and lesser tubercle. Its upper surface is convex and marked by three impressions; the highest of these gives insertion to the *Supraspinatus*; the middle, to the *Infraspinatus*; the lowest one, and the bone for about 2.5 cm. below it, to the *Teres minor*. The lateral surface of the greater tubercle is convex, rough, and continuous with the lateral surface of the body.

The **lesser tubercle**, more prominent than the greater, is situated in front, and is directed forwards and medialwards. On its upper and front part is an impression for the insertion of the tendon of the *Subscapularis*.

The tubercles are separated from each other by the *intertubercular sulcus* (bicipital groove), which lodges the long tendon of the *Biceps brachii*, transmits a branch of the anterior humeral circumflex artery to the shoulder-joint, and gives insertion to the tendon of the *Latissimus dorsi*. The sulcus diminishes in depth as it descends, and, near the junction of the upper with the middle third of the bone, is continuous with the anteromedial surface. The lips of the sulcus are called, respectively, the *crests of the greater and lesser tubercles* (bicipital ridges), and form the upper parts of the anterior and medial borders of the body of the bone.

The **body** or shaft, almost cylindrical above, but prismatic and flattened below, has three borders and three surfaces.

The **anterior border** runs from the front of the greater tubercle to the coronoid fossa, and separates the anteromedial from the anterolateral surface. Its upper part, the crest of the greater tubercle, serves for the insertion of the tendon

FIG. 367.—Left humerus. Anterior view.

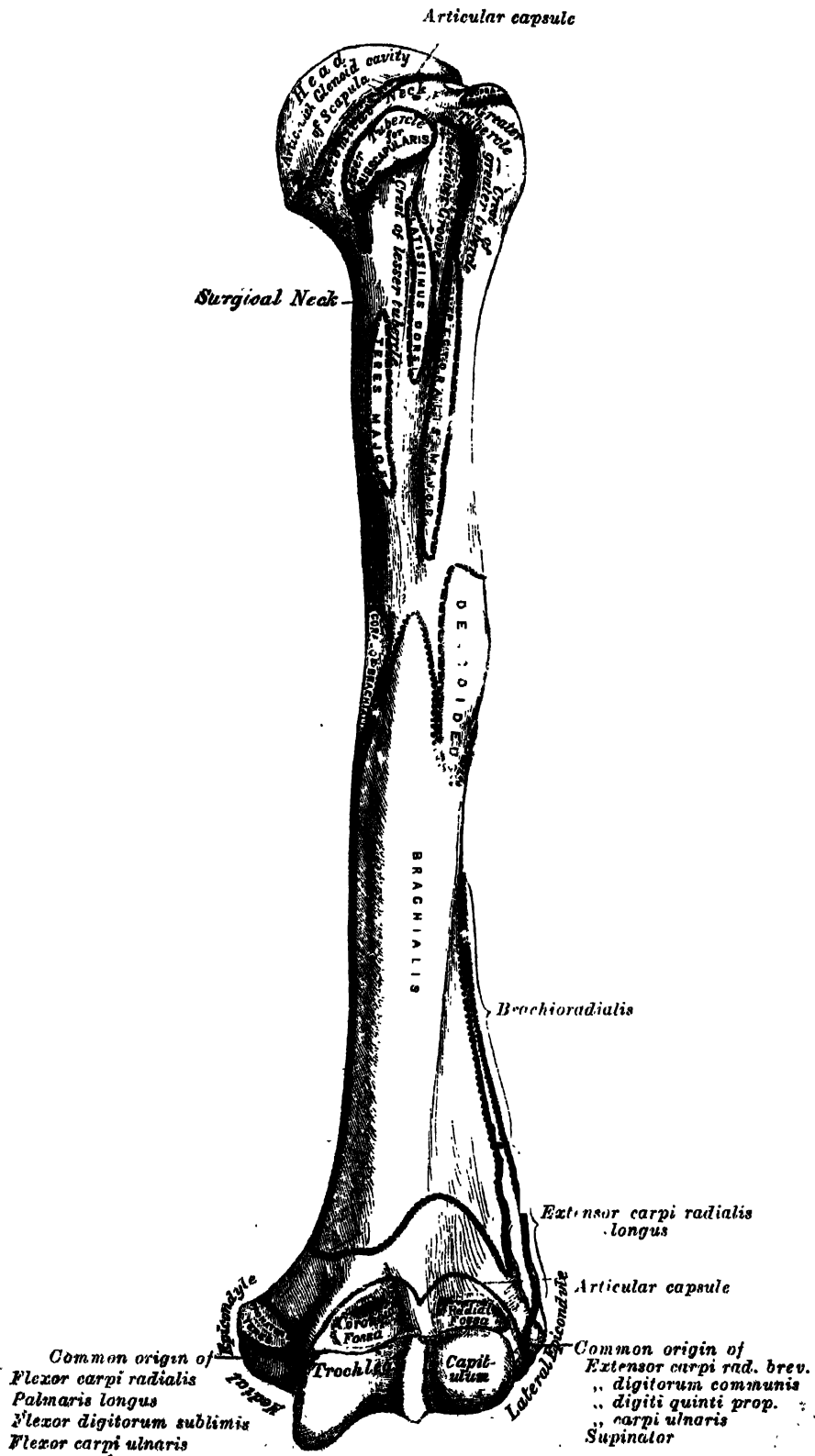
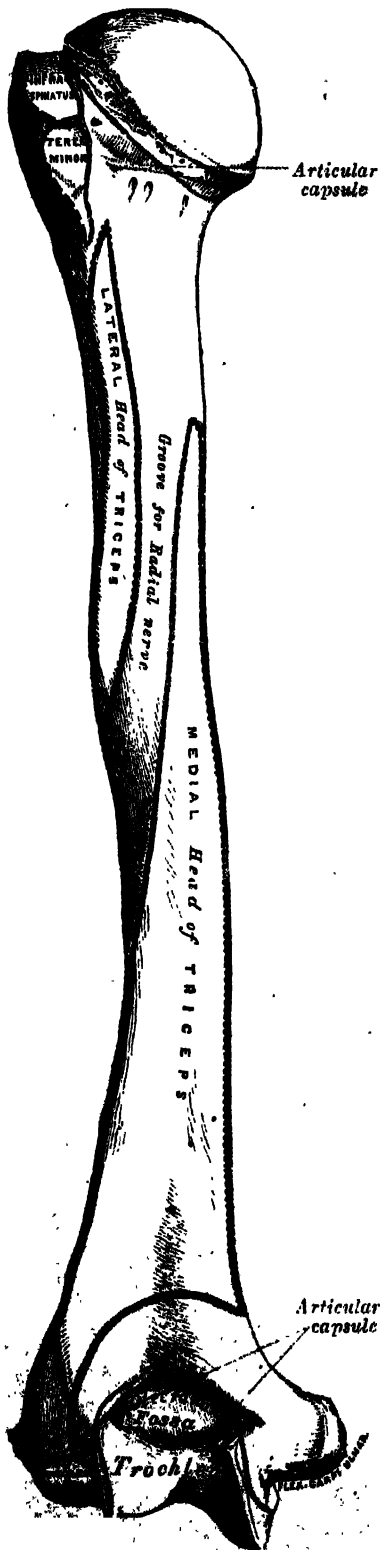


FIG. 368.—Left humerus.
Posterior view.



of the *Pectoralis major*. Its middle part forms the anterior boundary of the *deltoid tuberosity*; its lower part is smooth and rounded, and affords attachment to the *Brachialis*.

The *lateral border* runs from the back of the greater tubercle to the lateral epicondyle, and separates the antero-lateral from the posterior surface. Its upper half, rounded and indistinctly marked, gives insertion to the lower part of the *Teres minor*, and origin to the lateral head of the *Triceps brachii*; its middle part is traversed by a shallow oblique depression, the *sulcus nervi radialis* (musculospiral groove). Its lower part forms a prominent rough margin, the *lateral supracondylar ridge*, which is curved forwards, and gives attachment to the lateral intermuscular septum. The proximal two-thirds of this ridge give origin to the *Brachioradialis*; the distal third, to the *Extensor carpi radialis longus*.

The *medial border* extends from the lesser tubercle to the medial epicondyle and separates the anteromedial from the posterior surface. Its upper part, the crest of the lesser tubercle, gives insertion to the tendon of the *Teres major*. About the middle is a slight impression for the insertion of the *Coracobrachialis*, and just below this is the *nutrient canal*, directed downwards; sometimes there is a second nutrient canal at the commencement of the radial sulcus. The inferior third forms the *medial supracondylar ridge* which gives attachment to the medial intermuscular septum, and is prominent below.

The *anterolateral surface* is directed lateralwards above, where it is smooth, rounded, and covered by the *Deltoides*; forwards and lateralwards below, where it is slightly concave from above downwards, and gives origin to part of the *Brachialis*. About the middle of this surface is a rough elevation, triangular in shape with the apex below, the *deltoid tuberosity* for the insertion of the *Deltoides*; below this is the *sulcus nervi radialis*, which is directed from behind, forwards, and downwards, and transmits the *radial nerve* and *arteria profunda brachii*.

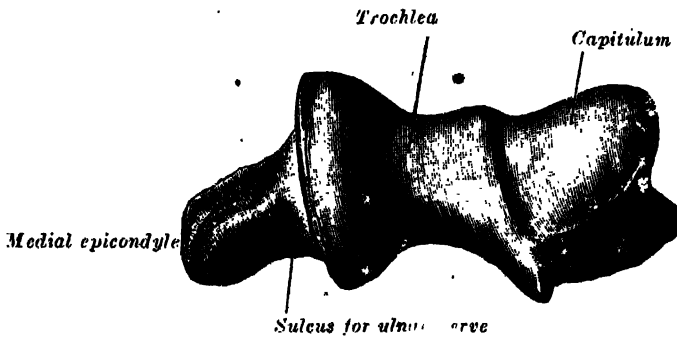
The *anteromedial surface*, less extensive than the anterolateral, is directed forwards above, forwards and medialwards below; its upper part, which is narrow, forms the floor of the *intertubercular sulcus* and gives insertion to the tendon of the *Latissimus dorsi*; its middle part is slightly rough for the attachment of some of the fibres of the tendon of insertion of the *Coracobrachialis*. Its

lower part is smooth, concave from above downwards, and gives origin to the *Brachialis*.*

The *posterior surface* appears somewhat twisted, so that its upper part is directed a little medialwards, its lower part backwards. Nearly the whole of this surface is covered by the lateral and medial heads of the *Triceps brachii*, the former arising above, the latter below the radial sulcus.

The lower extremity (fig. 369) is flattened from before backwards, and curved slightly forwards; it ends in a broad, articular surface which is divided into two parts by a smooth ridge. Projecting on either side, at a higher level than the articular surface, are the lateral and medial epicondyles. The *articular surface* is curved slightly forwards, and its medial extremity is lower than the lateral. The lateral portion of this surface is a smooth, rounded eminence, named the *capitulum* of the humerus; it articulates with the cup-shaped depression on the head of the radius, and is limited to the front and lower part of the bone. On the medial side of the capitulum is a shallow groove, in which the medial margin of the head of the radius is received; above the front part of the capitulum is a small depression, the *radial fossa*, which receives the anterior border of the head of the radius, when the forearm is flexed. The

FIG. 369.—Lower extremity of left humerus, from below.



medial portion of the articular surface is named the *trochlea* or pulley; it articulates with the semilunar notch of the ulna. Its central part consists of a deep groove which winds spirally from before backwards and lateralwards round the lower end of the bone; the groove is deeper behind where it expands to occupy the whole width of the trochlea. The medial margin is prominent, and forms about two-thirds of a circle, and the adjacent portion of the articular surface is convex on the front and lower part of the bone; on the posterior surface the convexity disappears. The lateral margin is rounded in front and below, where it is separated from the capitulum by a groove which receives the margin of the head of the radius; posteriorly the lateral margin of the trochlea is sharp and prominent. Above the front of the trochlea is a depression, the *coronoid fossa*, which receives the coronoid process of the ulna when the forearm is flexed, and above the back of it is a deep triangular depression, the *olecranon fossa*, in which the summit of the olecranon is received when the forearm is extended. These fossae are separated from one another by a thin lamina of bone, which is sometimes perforated by the *supratrochlear foramen*; they are lined in the recent state by the synovial stratum, and their margins

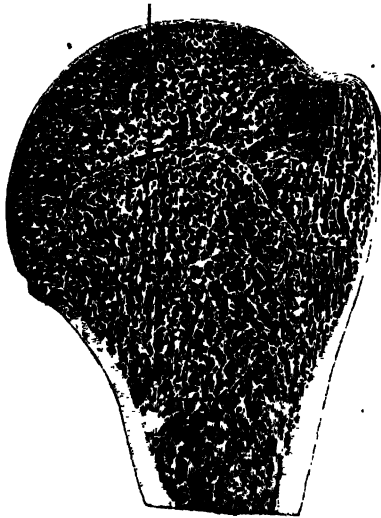
* A hook-shaped process of bone, the *supracondylar process*, varying from 2 mm. to 20 mm. in length, is not infrequently found projecting from the anteromedial surface of the body of the humerus 5 cm. above the medial epicondyle. It is curved downwards and forwards, and its pointed end is connected to the medial border, just above the epicondyle, by a fibrous band which gives origin to a portion of the *Pronator teres*; through the arch completed by this fibrous band the median nerve and brachial artery pass, when these structures deviate from their usual course. Sometimes the nerve alone is transmitted through it, or the nerve may be accompanied by the ulnar artery, in cases of high division of the brachial. A well-marked groove is usually found behind the process, in which the nerve and artery are lodged. This arch is the homologue of the supracondylar foramen found in many animals, and probably serves in them to protect the nerve and artery from compression during the contraction of the muscles in this region.

afford attachment to the fibrous stratum of the articular capsule of the elbow-joint. The *lateral epicondyle* is small and tuberculated, and curved a little forwards; it gives attachment to the radial collateral ligament of the elbow-joint and to a tendon common to the origin of the Supinator and some of the extensor muscles of the forearm. The *medial epicondyle*, larger and more prominent than the lateral, is directed a little backwards; it gives attachment to the ulnar collateral ligament of the elbow-joint, to the Pronator teres, and to a common tendon of origin of some of the flexor muscles of the forearm; the ulnar nerve and posterior ulnar recurrent artery run in a groove (*sulcus nervi ulnaris*) on the back of this epicondyle. The epicondyles are continuous above with the supracondylar ridges.

Structure.—The extremities consist of spongy substance, covered with a thin layer of compact bone (fig. 370); the body is composed of a cylinder of compact bone, thicker at the centre than towards the extremities, and contains a large medullary canal which extends along its whole length.

FIG. 370.—Longitudinal section of head of left humerus.

Epiphysial line



Ossification (figs. 371, 372). — The humerus is ossified from eight centres, one for each of the following parts: the body, the head, the greater tubercle, the lesser tubercle, the capitulum and lateral part of the trochlea, the medial part of the trochlea, and one for each epicondyle. The centre for the body appears near the middle of the bone in the eighth week of foetal life, and gradually extends towards the extremities, which at birth are cartilaginous. During the first year, occasionally before birth, ossification begins in the head of the bone, during the third year in the greater tubercle, and during the fifth in the lesser tubercle. By the sixth year the centres for the head and tubercles have joined to form a single large epiphysis, which fuses with the body about the twentieth year. The lower end of the humerus is ossified as follows. At the end of the second year ossification begins in the capitulum and extends medial-

wards to form the chief part of the articular surface; the centre for the medial part of the trochlea appears about the twelfth year. Ossification begins in the medial epicondyle about the fifth year, and in the lateral about the thirteenth or fourteenth year. The centre for the lateral epicondyle fuses with those for the trochlea and capitulum and the epiphysis thus formed unites with the body about the sixteenth or seventeenth year; the medial epicondyle unites with the body about the eighteenth year.

Applied Anatomy.—The upper end of the humerus, though the first to ossify, is the last to join the body, and the length of the bone is mainly due to growth from the upper epiphysial plate. Hence, in cases of amputation through the arm in young subjects, the humerus continues to grow considerably, and the lower end of the bone, which immediately after the operation was covered with a thick cushion of soft tissue, begins to project, thinning the soft parts and rendering the stump conical. This may necessitate the removal of about 5 cm. of the bone, and even after this operation a recurrence of the conical stump may take place. The region of the upper epiphysis is a common site for the growth of tumours, both innocent and malignant.

Fractures of the humerus are common. The bone may be broken by direct or indirect violence, like the other long bones; but, in addition to this, it is probably more frequently fractured by muscular action than any other bone of this class, it is usually the body of the bone, just below the insertion of the Deltoides, which is thus broken, and the accident has been known to happen from throwing a stone. Fractures of the upper end may take place either through the anatomical or surgical neck, or a separation of the greater tubercle may occur. Fracture of the anatomical neck is a very rare accident; in fact, it is doubted by some whether it ever occurs. Fracture of the surgical neck of the bone is not uncommon, and impaction may occur; on the other hand, the upper end of the lower segment may be displaced into the axilla and may damage the vessels or nerves.

The fracture somewhat closely simulates dislocation of the shoulder-joint, but can be distinguished by the fact that the head of the bone remains in its normal position and the great tubercle still forms the most prominent point of the shoulder. Separation of the upper epiphysis sometimes occurs in the young subject, and is marked by a characteristic deformity, consisting in the presence of an abrupt projection at the front of the joint a short distance below the coracoid process, caused by the upper end of the diaphysis. In fractures of the body of the humerus the lesion may take place at any point, but appears

FIG. 371.—Plan of ossification of the humerus.

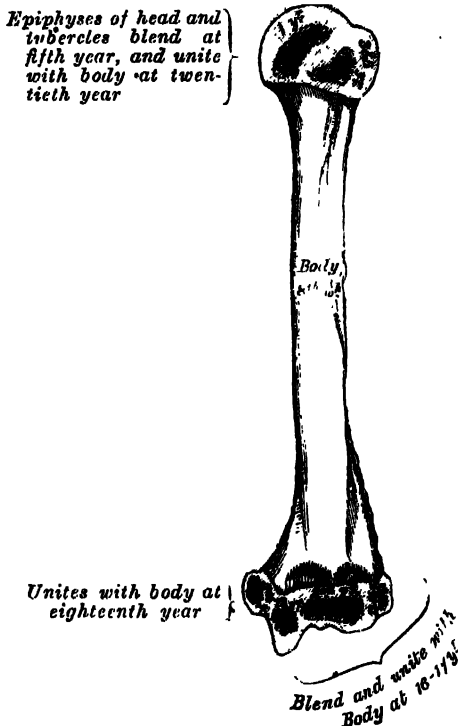
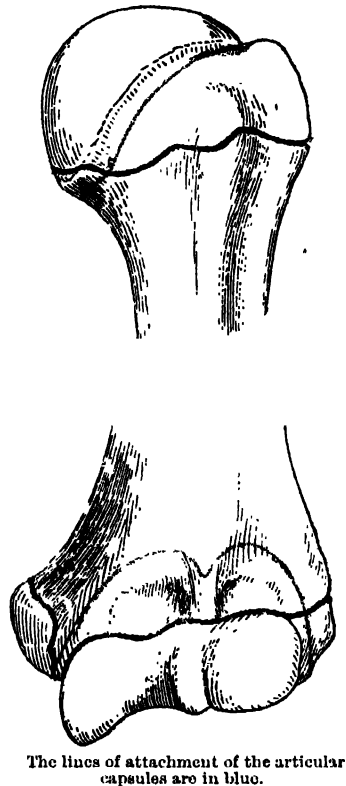


FIG. 372.—Epiphysial lines of humerus in a young adult. Anterior aspect.



The lines of attachment of the articular capsules are in blue.

to be more common in the lower than the upper part of the bone. The points of interest in connexion with these fractures are: (1) that the radial nerve may be injured as it lies in the groove on the bone, or may become involved in the callus which is subsequently thrown out; and (2) the frequency of non-union, which is believed to be more common in the humerus than in any other bone. In fractures of the lower end it is important to distinguish between those that involve the elbow-joint and those that do not; the former are always serious, as they may lead to impairment of the utility of the limb; they include the T-shaped fracture and oblique fractures which involve the articular surface. Those which do not involve the joint are the transverse fracture above the epicondyles, and the so-called epitrochlear fracture, where the tip of the medial epicondyle is broken off, generally by direct violence.

THE RADIUS

The radius (figs. 373 and 374) is situated on the lateral side of the forearm. Its upper end is small, and forms only a small part of the elbow-joint; its lower end is large, and forms a large part of the wrist-joint. It is a long bone, prismatic in form and slightly curved longitudinally.

The upper extremity consists of a head, neck, and tuberosity. The head is of a cylindrical form, and on its upper surface is a shallow cup or fovea for articulation with the capitulum of the humerus. The circumference of the head is smooth; it is broad medially where it articulates with the radial notch

FIG. 373.—Bones of left forearm. Volar aspect.

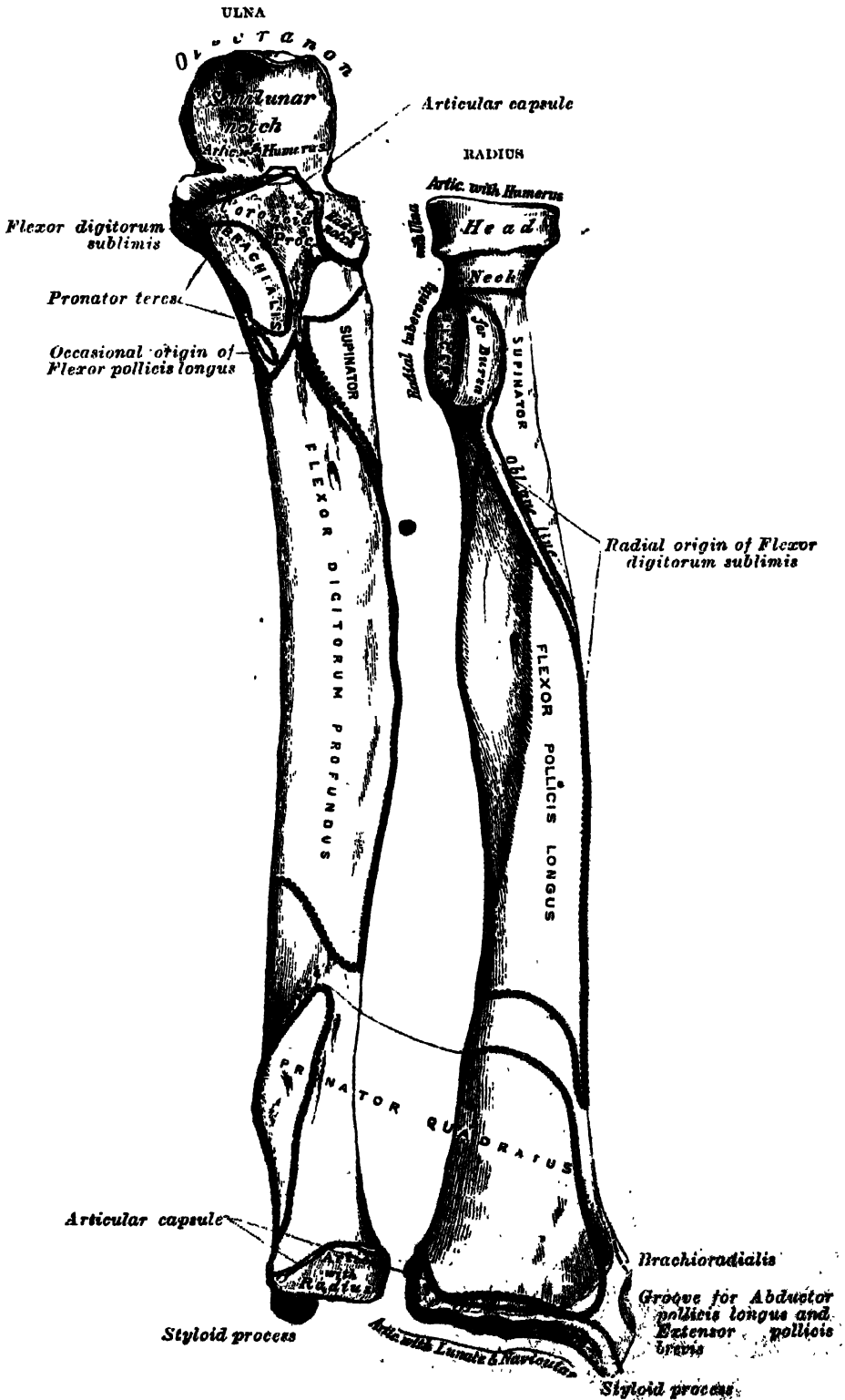
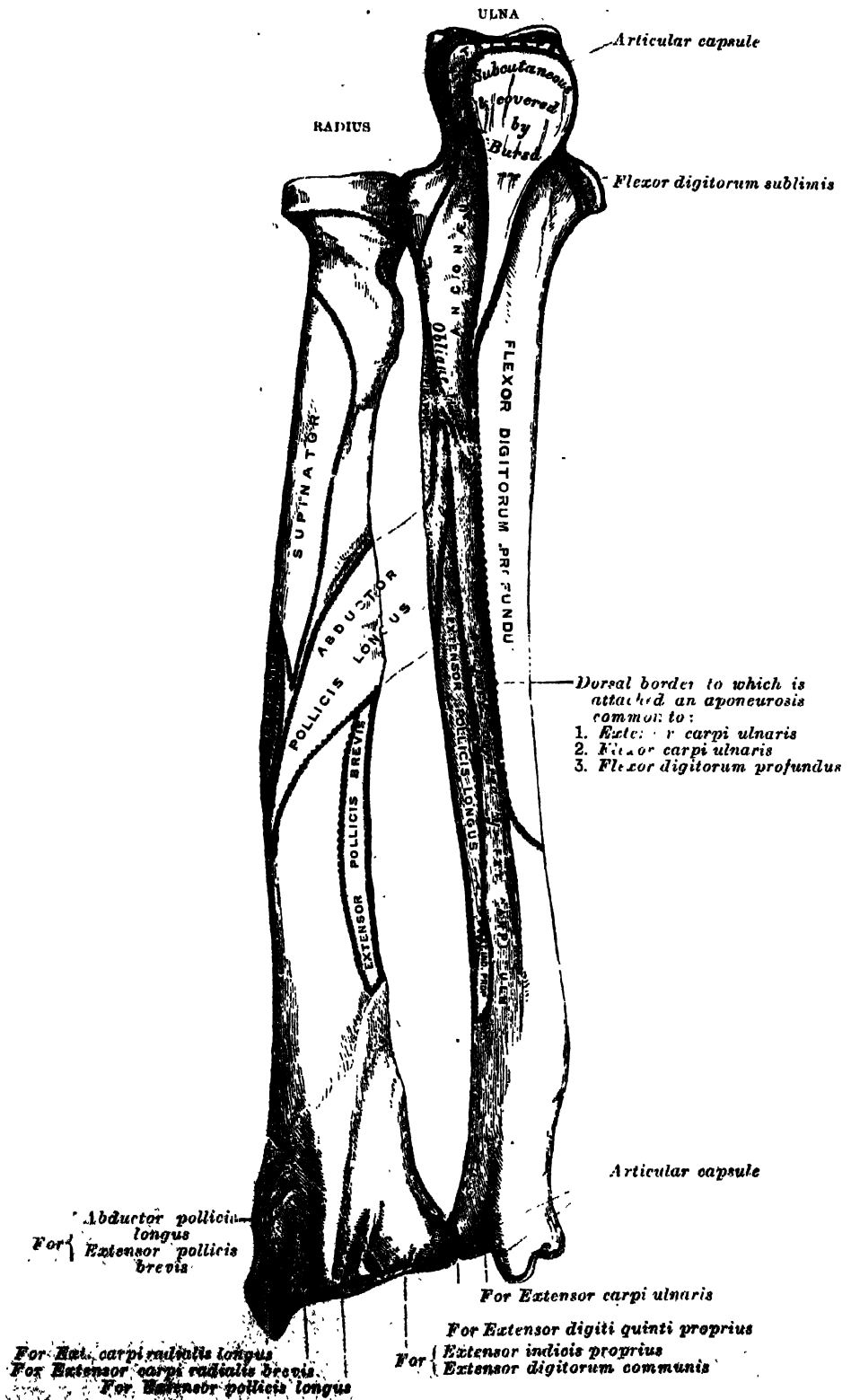


Fig. 374.—Bones of left forearm. Dorsal aspect.



of the *ulna*, narrow in the rest of its extent, which is embraced by the *annular ligament*. The head is supported on a round, smooth, and constricted *neck*. Below the medial part of the neck is an eminence, the *radial tuberosity*; its surface is divided into a posterior rough portion for the insertion of the tendon of the *Biceps brachii*, and an anterior smooth portion on which a *bursa* is interposed between the tendon and the bone.

The *body* or *shaft* is prismoid in form, narrower above than below, and slightly curved, so as to be convex laterally. It has three borders and three surfaces.

The *volar* or *anterior border* separates the volar from the lateral surface, and extends from the lower part of the tuberosity above, to the anterior part of the base of the styloid process below. Its upper part is prominent, and from its oblique direction has received the name of the *oblique line*; it gives origin to the *Flexor digitorum sublimis* and *Flexor pollicis longus*; the surface above the line gives insertion to part of the *Supinator*. The middle part of the volar border is indistinct and rounded. The lower part is prominent, and gives insertion to the *Pronator quadratus*, and attachment to the *dorsal carpal ligament*; it ends in a small tubercle, into which the tendon of the *Brachioradialis* is inserted.

The *dorsal* or *posterior border* separates the dorsal from the lateral surface; it is well-marked only in the middle third of the bone.

The *interosseous crest* or *medial border* separates the volar from the dorsal surface, and gives attachment to the antibrachial interosseous membrane (fig. 378); it begins above, at the back part of the tuberosity, and its upper part is rounded and indistinct. It becomes sharp and prominent as it descends, and at its lower part divides into two ridges which are continued to the anterior and posterior margins of the ulnar notch; to the posterior ridge the lower part of the antibrachial interosseous membrane is attached while the triangular surface between the ridges gives insertion to part of the *Pronator quadratus*.

The *volar* or *anterior surface* is concave in its upper three-fourths, and gives origin to the *Flexor pollicis longus*; its lower fourth is broad and flat, and affords insertion to the *Pronator quadratus*. A prominent ridge limits the insertion of the *Pronator quadratus* below, and between this and the inferior border is a triangular rough surface for the attachment of the *volar radiocarpal ligament*. At the junction of the upper with the middle third of this surface is the *nutrient canal*, directed obliquely upwards.

The *dorsal surface* is convex and smooth in the upper third of its extent, and covered by the *Supinator*. Its middle third, broad and slightly concave, gives origin to the *Abductor pollicis longus* above, and to the *Extensor pollicis brevis* below. Its lower third, broad and convex, is covered by the tendons of the muscles which subsequently run in the grooves on the lower end of the bone.

The *lateral surface* is convex; its upper third gives insertion to the *Supinator*; near its centre is a rough ridge, for the insertion of the *Pronator teres*; its lower part is covered by the tendons of the *Abductor pollicis longus* and *Extensor pollicis brevis*.

The *lower extremity* is large and is provided with two articular surfaces—one below, for the carpus, and another at the medial side, for the ulna. The carpal articular surface (fig. 379) is triangular, concave, smooth, and divided by a slight anteroposterior ridge into two parts. The lateral, triangular part, articulates with the navicular bone; the medial, quadrilateral part, with the lunate bone. The articular surface for the ulna is called the *ulnar notch* (sigmoid cavity); it is narrow, concave, smooth, and articulates with the head of the ulna. These two articular surfaces are separated by a prominent ridge, to which the base of the *triangular articular disc* is attached; this disc separates the wrist-joint from the distal radio-ulnar articulation. The lower end of the bone has three non-articular surfaces—volar, dorsal, and lateral. The *volar surface*, rough and irregular, affords attachment to the *volar radiocarpal ligament*. The *dorsal surface* is convex, affords attachment to the *dorsal radiocarpal ligament*, and is marked by three grooves. Enumerated from the lateral side, the first groove is broad, but shallow, and subdivided by a slight ridge; the lateral part transmits the tendon of the *Extensor carpi radialis longus*, the medial, the tendon of the *Extensor carpi radialis brevis*.

The second groove is deep but narrow, and bounded laterally by a sharp ridge; it runs obliquely downwards and lateralwards, and transmits the tendon of the Extensor pollicis longus. The third groove is broad, for the passage of the tendons of the Extensor indicis proprius and Extensor digitorum communis. The *lateral surface* is prolonged obliquely downwards into a strong, conical projection, the *styloid process*, the base of which gives attachment to the tendon of the Brachioradialis, the apex to the radial collateral ligament of the wrist-joint. On the lateral surface of this process is a flat groove, for the tendons of the Abductor pollicis longus and Extensor pollicis brevis.

FIG. 375.—Plan of ossification of the radius. From three centres.

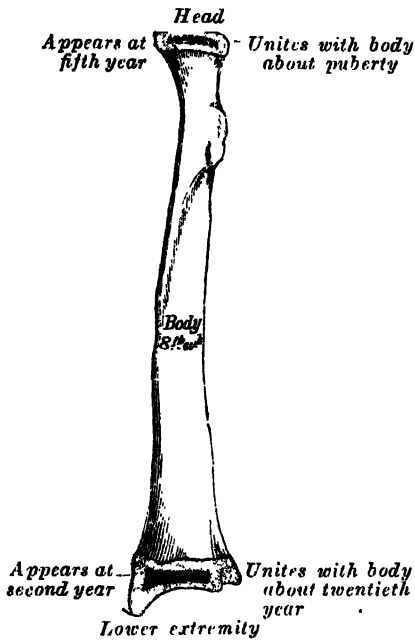
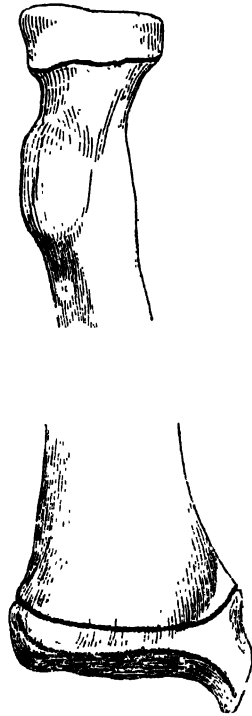


FIG. 376.—Epiphysial lines of radius in a young adult. Anterior aspect.



The line of attachment of the articular capsule of the wrist-joint is in blue.

Structure.—The structure of the radius is like that of the other long bones.

Ossification (figs. 375, 376).—The radius is ossified from three centres: one for the body, and one for either end. That for the body appears near the middle of the bone, in the eighth week of foetal life. About the close of the second year, ossification begins in the lower end; and at the fifth year, in the upper end. The upper epiphysis fuses with the body at the age of seventeen or eighteen years, the lower about the age of twenty. An additional centre, sometimes found in the radial tuberosity, appears about the fourteenth or fifteenth year.

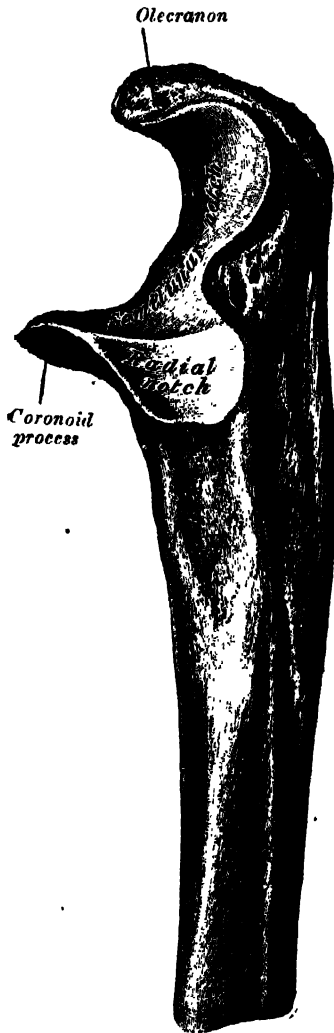
THE ULNA

The ulna (figs. 373 and 374) is placed at the medial side of the forearm, parallel with the radius. The upper extremity is thick and strong, and forms a large part of the elbow-joint; the body or shaft diminishes in size from above downwards; the lower extremity is small, and is excluded from the wrist-joint by the interposition of an articular disc:

On the upper extremity, (fig. 377) are two curved processes, the olecranon and the coronoid process; and two concave articular cavities, the semilunar and radial notches.

The olecranon is a thick, curved eminence, on the upper and posterior part of the ulna. It is bent forwards at the summit so as to present a prominent lip which is received into the olecranon fossa of the humerus when the forearm is extended. Its base is contracted where it joins the body, and is

FIG. 377.—Upper part of left ulna.
Lateral aspect.



the narrowest part of the upper end of the ulna. Its posterior surface, directed backwards, is triangular, smooth, subcutaneous, and is covered by a bursa. Its superior surface, of quadrilateral form, is marked behind by a rough impression for the insertion of the Triceps brachii, and in front, close to the margin, by a slight groove for the attachment of part of the articular capsule of the elbow-joint; between the groove for the articular capsule and the impression for the Triceps brachii is a smooth area which is separated from the tendon of the Triceps brachii by a bursa. Its anterior surface forms the upper part of the semilunar notch. On its borders are grooves continuous with that on the anterior part of the superior surface; that on the medial border gives attachment to the posterior part of the ulnar collateral ligament; that on the lateral border to part of the articular capsule. From the medial border a part of the Flexor carpi ulnaris arises; to the lateral the Anconæus is attached.

The coronoid process is a prismatic eminence projecting forwards from the front of the upper extremity of the ulna. Its base is continuous with the body of the bone, and is of considerable strength. Its apex is pointed, slightly curved upwards, and is received into the coronoid fossa of the humerus when the forearm is flexed. Its upper surface forms the lower part of the semilunar notch. Its antero-inferior surface is concave, and marked by a rough impression for the insertion of the Brachialis; this impression extends on to the upper part of the body of the bone. At the junction of this surface with the front of the body is a rough eminence, the tuberosity of the ulna, which gives insertion to a part of the Brachialis; to the lateral

border of this tuberosity the oblique cord is attached. On its lateral surface is a narrow, oblong, articular depression, the radial notch. Its medial surface ends superiorly in a prominent, free margin which gives attachment to part of the ulnar collateral ligament. At the front part of this surface is a round eminence for the origin of a small part of the Flexor digitorum sublimis; behind the eminence is a depression for part of the origin of the Flexor digitorum profundus; descending from the eminence is a ridge which gives origin to the ulnar head of the Pronator teres. Frequently a rounded muscular bundle of the Flexor pollicis longus arises by a tendinous slip from the lower part of the coronoid process.

The semilunar notch (greater sigmoid cavity), for articulation with the trochlea of the humerus, is a large depression, formed by the olecranon and the coronoid process. It is concave from above downwards and its

part is constricted and sometimes crossed by a groove; it is divided into a medial and a lateral portion by a smooth ridge running from the summit of the olecranon to the tip of the coronoid process. The medial portion is the larger, and is slightly concave transversely; the lateral is convex above, slightly concave below.

The radial notch (lesser sigmoid cavity) (fig. 377) is an oblong, articular depression on the lateral side of the coronoid process for the reception of the circumferential articular surface of the head of the radius. It is concave from before backwards, and its anterior and posterior extremities serve for the attachment of the annular ligament.

The body or shaft, at its upper part, is prismatic in form, and curved, with its convexity directed posteriorly and lateralwards; its central part is prismatic and straight; its lower part is rounded and bent a little lateralwards. The body tapers gradually from above downwards, and has three borders and three surfaces.

The *volar* or *anterior* border separates the volar from the medial surface; it begins above at the prominent medial angle of the coronoid process, and ends below in front of the styloid process. Its upper part, well defined, and its middle portion, smooth and rounded, give origin to the *Flexor digitorum profundus*; its lower fourth forms a prominent ridge for the origin of the *Pronator quadratus*.

The *dorsal* border is subcutaneous, and separates the medial from the dorsal surface; it begins above at the apex of the triangular subcutaneous surface at the back part of the olecranon, and ends below at the back of the styloid process; its upper three-fourths are well marked and give attachment to an aponeurosis which affords a common origin to the *Flexor carpi ulnaris*, the *Extensor carpi ulnaris*, and the *Flexor digitorum profundus*; its lower fourth is smooth and rounded.

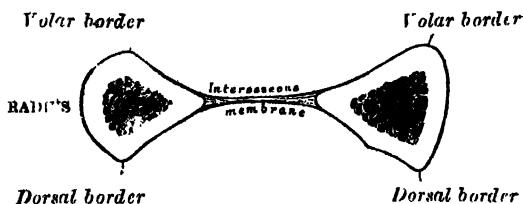
The *interosseous crest* or *lateral* border separates the volar from the dorsal surface and gives attachment to the antibrachial interosseous membrane (fig. 378); it begins above by the union of two lines, which converge from the extremities of the radial notch and enclose between them a triangular area for the origin of part of the *Supinator*; it ends below at the head of the ulna. Its upper part is sharp and prominent, its lower fourth smooth and rounded.

The *volar* or *anterior* surface is broader above than below; its upper three-fourths are concave and give origin to the *Flexor digitorum profundus*; its lower fourth is covered by the *Pronator quadratus* and is separated from the remaining portion by a ridge which is directed obliquely downwards and medialwards, and marks the extent of origin of the *Pronator quadratus*. At the junction of the upper with the middle third of this surface is the nutrient canal, directed obliquely upwards.

The *dorsal* surface, directed backwards and lateralwards, is broad above; convex and somewhat narrower in the middle; narrow and rounded below. On its upper part is an oblique ridge which runs downwards from the dorsal end of the radial notch to the dorsal border; the upper part of the ridge affords attachment to the *Supinator*, and the triangular surface above it receives the insertion of the *Anconeus*. Below this ridge the dorsal surface is subdivided by a *perpendicular line*, into two parts: the medial part is smooth, and covered by the *Extensor carpi ulnaris*; the lateral gives origin from above downwards to the *Abductor pollicis longus*, the *Extensor pollicis longus*, and the *Extensor indicis proprius*.

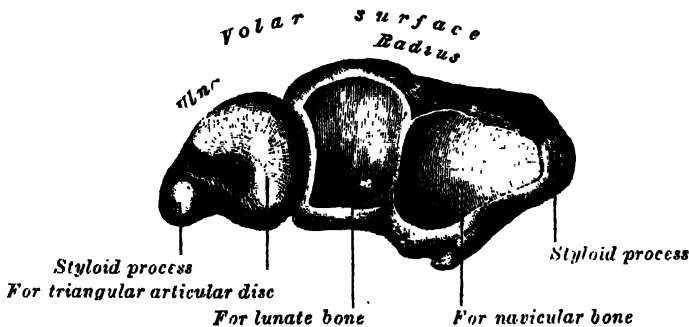
The *medial* surface is broad and concave above, narrow and convex below. Its upper three-fourths give origin to the *Flexor digitorum profundus*; its lower fourth is subcutaneous.

Fig. 378.—Transverse section of left radius and ulna, showing attachment of interosseous membrane.



The lower extremity of the ulna is small, and has two eminences; the lateral and larger is termed the head of the ulna; the medial, narrower and more projecting, the styloid process. The head presents an articular surface, the distal part of which, of a semilunar form (fig. 379), is directed downwards, and comes into contact with the upper surface of the triangular articular disc which separates the ulna from the radiocarpal or wrist-joint; the remaining portion, directed lateralwards, is narrow and convex, and is received into the ulnar notch of the radius. The *styloid process* projects from the medial and posterior part of the bone; it descends a little lower than the head, and its rounded apex affords attachment to the ulnar collateral ligament of the wrist-joint. The head is separated from the styloid process, below by a depression for the attachment of the apex of the triangular articular disc, and behind by a shallow groove for the tendon of the Extensor carpi ulnaris.

FIG. 379.—Lower extremities of right radius and ulna, from below.



Structure.—The structure of the ulna is similar to that of the other long bones.

Ossification (figs. 380, 381).—The ulna is ossified from three centres: one each for the body, the inferior extremity, and the top of the olecranon. Ossification begins near the middle of the body, about the eighth week of foetal life, and soon extends through the greater part of the bone. About the fourth year, a centre appears in the middle of the head, and extends into the styloid process. About the tenth year, a centre appears in the olecranon near its extremity, but the chief part of this process is formed by an upward extension of the body; sometimes the extremity of the olecranon is ossified from two centres. The upper epiphysis joins the body about the sixteenth, the lower about the twentieth year.

Applied Anatomy.—The bones of the forearm are more often broken together than separately. Fractures of both bones may be produced by either direct or indirect violence, though more commonly by direct violence. When indirect force is applied to the forearm the radius as a rule gives way, though both bones may suffer. Fractures from indirect force generally take place somewhere about the middle of the bones, while those from direct violence may occur at any part, but are most frequent in the lower half of the bones. The fractures are usually transverse, but may be more or less oblique. A point of interest in connexion with these fractures is the tendency for the two bones to unite across the interosseous membrane; the limb should therefore be put up in a position midway between supination and pronation, which is not only the most comfortable position, but also separates the bones most widely from each other. Anterior and posterior splints are applied in these cases, and should be rather wider than the limb, so as to prevent any side pressure on the bones.

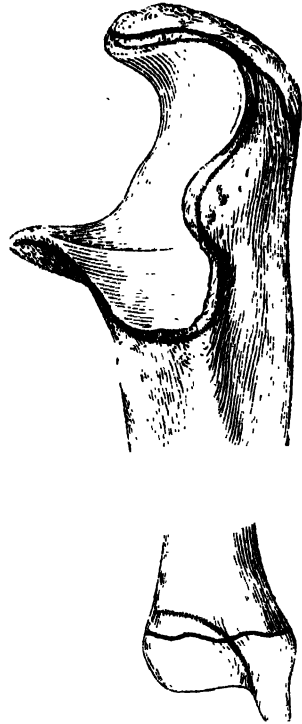
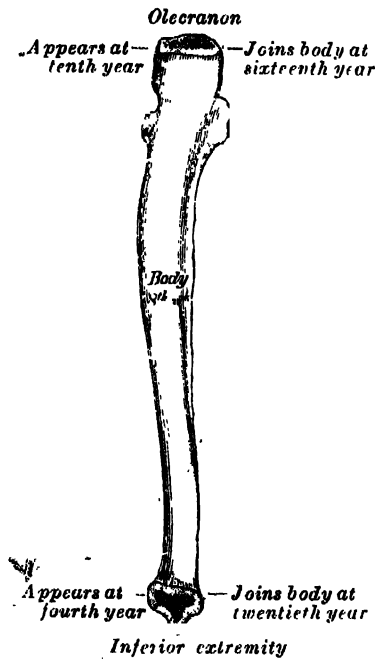
The special fractures of the ulna are: (1) Fracture of the olecranon, which is usually caused by direct violence, by falls on the elbow with the forearm flexed, but occasionally by muscular action in sudden contraction of the Triceps brachii; the most common site of this fracture is at the constricted portion where the olecranon joins the body of the bone, and the fracture is usually transverse; but any part may be broken, and even a thin shell may be torn off. Fractures from direct violence are occasionally comminuted. If the fibrous structures around the process are not torn the displacement is slight; otherwise the olecranon may be drawn up for a very considerable distance. (2) Fracture of the coronoid process may occur as a complication of dislocation backwards of the bones of the forearm, but it is doubtful if it ever takes place as an uncomplicated injury. (3) Fractures of the body of the ulna may occur at any part, but usually take place at or a little below the middle of the bone. They are generally the result of direct violence, but may

occur as a complication of dislocation of the radius. (4) The styloid process may be knocked off by direct violence.

Fractures of the radius may consist of: (1) Fracture of the head of the bone; this for the most part takes place in conjunction with some other lesion, but may occur as an uncomplicated injury. (2) Fracture of the neck also may occur, but is usually complicated with other injury. (3) Fractures of the body of the radius are very common, and may take place at any part of the bone. They may be caused by direct or indirect violence. In fracture of the upper third of the body—that is to say, above the insertion of the Pronator teres—the displacement is very great. The upper fragment is strongly supinated by the Biceps and Supinator, and flexed by the Biceps: while the lower fragment is pronated and drawn towards the ulna by the two Pronators. If such a fracture be put up in the ordinary position, midway between supination and pronation, the bone will unite

FIG. 381.—Epiphysial lines of ulna in a young adult. Lateral aspect.

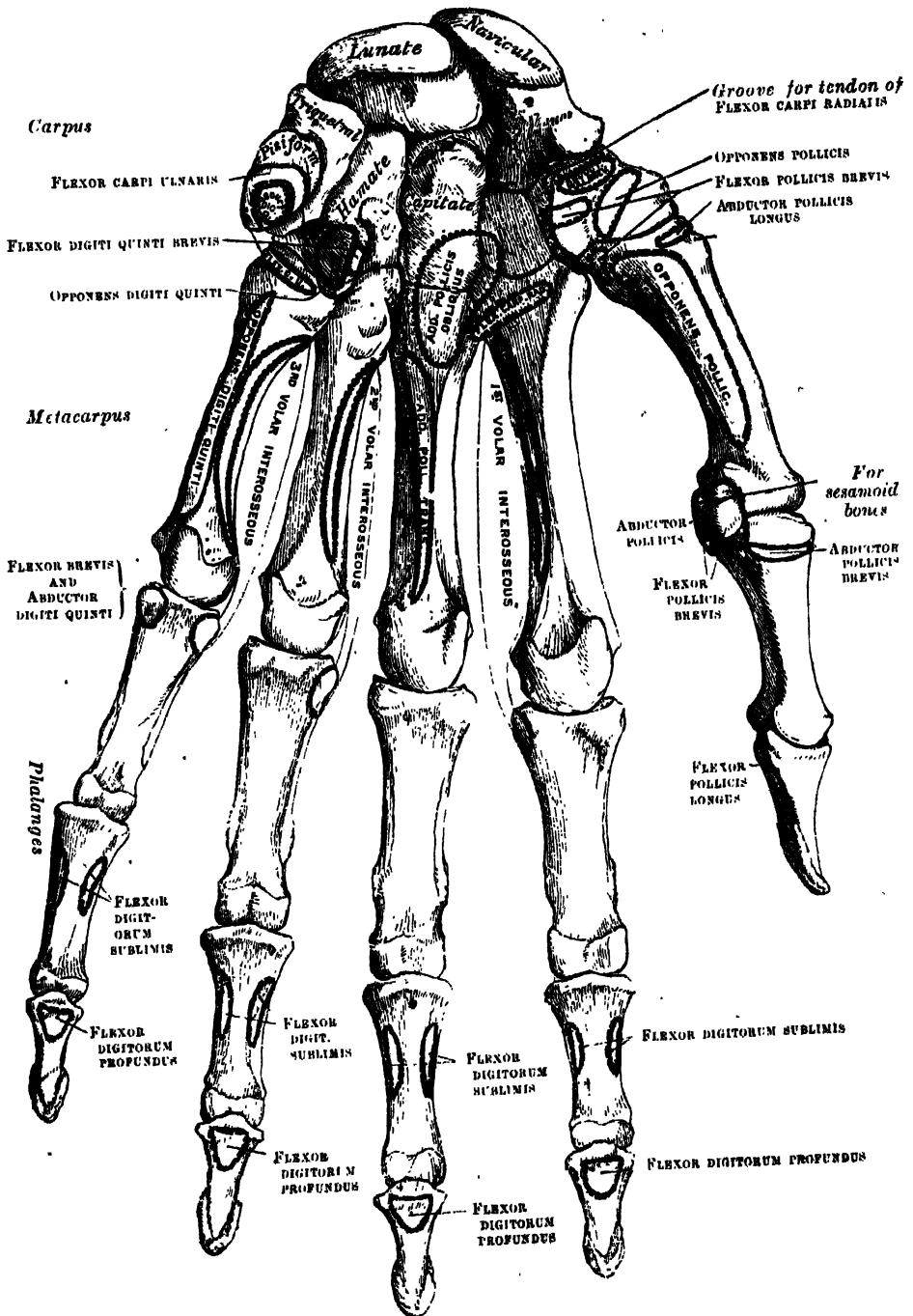
FIG. 380.—Plan of ossification of the ulna. From three centres.



The line of attachment of the articular capsules are in blue.

with the upper fragment in a position of supination, and the lower one in the mid-position, and thus considerable impairment of the movement of supination will result; the limb should therefore be put up with the forearm supinated. (4) The most important fracture of the radius is that of the lower end (Colles's fracture). The fracture is transverse, and generally takes place about 2.5 cm. from the lower extremity. It is caused by falls on the palm of the hand, and is an injury of advanced life, occurring more frequently in the female than in the male. In consequence of the manner in which the fracture is caused, the upper fragment is driven into the lower, and impaction commonly is the result; excess of violence may, however, disimpact, the lower fragment being split into two or more pieces, so that no fixation occurs. Separation of the lower epiphysis of the radius may take place in the young. This injury and Colles's fracture may be distinguished from other injuries in this neighbourhood—especially dislocation of the wrist, with which they are liable to be confounded—by observing the relative positions of the styloid processes of the ulna and radius. In the natural condition of parts, with the arm hanging by the side, the styloid process of the radius is on a lower level than that of the ulna. After fracture or separation of the epiphysis the styloid process of the radius is on the same level as, or on a higher level than, that of the ulna, whereas it would be unaltered in position in dislocation. Reduction in the case of Colles's fracture is usually easily effected by traction on the hand, the limb being subsequently splinted with the hand deflected towards the ulnar side.

FIG. 382.—Bones of the left hand. Volar surface.



THE SKELETON OF THE HAND

The skeleton of the hand (figs. 382 and 383) consists of three segments : (1) the carpus or wrist bones ; (2) the metacarpus or bones of the palm ; and (3) the phalanges or bones of the digits.

THE CARPUS

The **carpal bones** (*ossa carpi*), eight in number, are arranged in two rows. Those of the proximal row, from the radial to the ulnar side, are named the navicular, lunate, triquetral, and pisiform bones ; those of the distal row, in the same order, are the greater multangular, lesser multangular, capitate, and hamate bones.

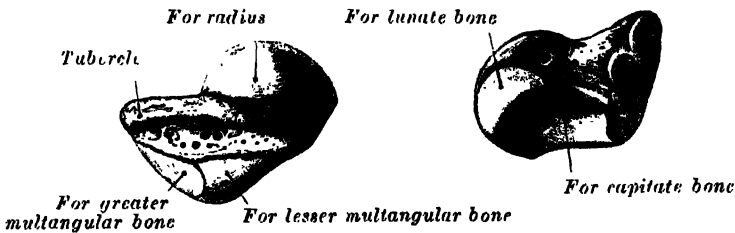
COMMON CHARACTERISTICS OF THE CARPAL BONES

Each bone (excepting the pisiform) presents six surfaces. Of these the *volar* or *anterior* and the *dorsal* or *posterior surfaces* are rough, for ligamentous attachment ; the *dorsal surfaces* are the broader, except in the navicular and lunate bones. The *superior* or *proximal*, and *inferior* or *distal surfaces* are articular, the superior generally convex, the inferior concave ; the *medial* and *lateral surfaces* are also articular where they are in contact with contiguous bones, otherwise they are rough and tuberculated. The structure in all is similar, viz. spongy substance enclosed in a layer of compact bone.

THE NAVICULAR BONE (*Os NAVICULARE MANUS*) 5~

The **navicular bone** (fig. 384), the largest of the proximal row, has received its name from its fancied resemblance to a boat. It is situated at the radial

FIG. 384.--The left navicular bone.

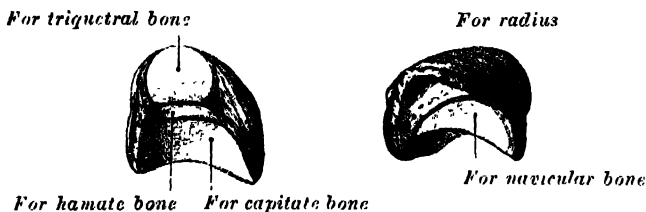


side of the carpus, its long axis being from above downwards, lateralwards, and forwards. The *superior surface* is convex, smooth, of triangular shape, and articulates with the lower end of the radius. The *inferior surface*, directed downwards and backwards, is also smooth, convex, and triangular ; it is divided by an indistinct ridge into a lateral part which articulates with the greater multangular bone, and a medial with the lesser multangular bone. On the *dorsal surface* is a narrow, rough groove which serves for the attachment of ligaments. The *volar surface* is concave above, but elevated at its lower and lateral part into a rounded *tubercle*, which is directed forwards and gives attachment to the transverse carpal ligament and sometimes to a few fibres of the *Abductor pollicis brevis*. The *lateral surface*, rough and narrow, gives attachment to the radial collateral ligament of the wrist. On the *medial surface* are two articular facets ; of these, the superior is flat and crescentic in shape, and articulates with the lunate bone ; the inferior is concave and forms with the lunate bone a concavity for the head of the capitate bone.

THE LUNATE BONE (OS LUNATUM) 34

The **lunate** or **semilunar** bone (fig. 385), distinguished by its deep concavity and crescentic outline, is situated in the centre of the proximal row of the carpus, between the navicular and triquetral bones. The *superior surface*, convex and smooth, articulates with the radius. The *inferior surface* is

FIG. 385.—The left lunate bone.



deeply concave, and of greater extent from before backwards than transversely: it articulates with the head of the capitate bone, and, by a long, narrow facet with the hamate bone. The *dorsal* and *volar* surfaces are rough, for the attachment of ligaments, the dorsal being the smaller. On the *lateral surface* is a semilunar facet for articulation with the navicular bone, and on the *medial surface* a quadrilateral facet for the triquetral bone.

THE TRIQUETRAL BONE (OS TRIQUETRUM) 35

The **triquetral** or **cuneiform** bone (fig. 386) may be distinguished by its pyramidal shape, and by an oval isolated facet for articulation with the pisiform bone. It is situated at the ulnar side of the proximal row of the carpus with its long axis from above downwards and medialwards. The *superior surface*

FIG. 386.—The left triquetral bone.

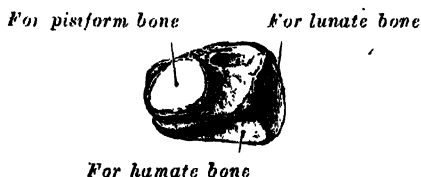


FIG. 387.—The left pisiform bone.



presents a medial rough non-articular portion, and a lateral convex smooth portion which articulates with the triangular articular disc of the wrist. The *inferior surface*, directed lateralwards, is concave, sinuously curved, and smooth for articulation with the hamate bone. The *dorsal surface* is rough for the attachment of ligaments. The *volar surface* displays, on its medial part, an oval facet for articulation with the pisiform bone; its lateral part is rough for ligamentous attachment. The *lateral surface*, or base of the pyramid, is marked by a flat, quadrilateral facet for articulation with the lunate bone. The *medial surface*, or summit of the pyramid, is pointed and gives attachment to the ulnar collateral ligament of the wrist.

THE PISIFORM BONE (OS PISIFORME) 36

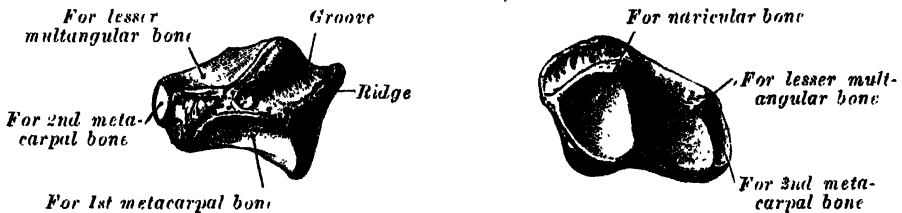
The **pisiform** bone (fig. 387) is situated in front of the triquetral bone, and may be known by its small size, and by its presenting a single, oval facet for articulation with that bone. This facet is on the dorsal surface of the bone, and its long axis is directed downwards and lateralwards. The *volar surface* is rounded and rough, and gives attachment to the Flexor carpi ulnaris. The

medial surface gives attachment to the Abductor digiti quinti and the dorsal carpal ligament; the pisometacarpal ligament is attached to the lower part of this surface. On the *anterolateral surface* is an oblique line or ridge, the distal part of which gives attachment to the volar carpal ligament. The lower part of the bone projects beyond the articular surface and presents a tubercle for the attachment of the pisohamate ligament.*

THE GREATER MULTANGULAR BONE (OS MULTANGULUM MAJUS) 4

The **greater multangular bone** or **trapezium** (fig. 388) may be distinguished by a deep groove on its volar surface. It is situated at the radial side of the carpus, between the navicular and first metacarpal bones. The

FIG. 388.—The left greater multangular bone.

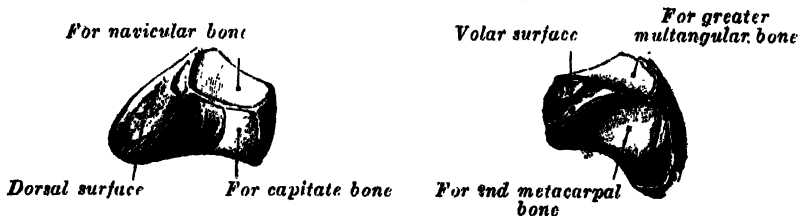


superior surface is directed upwards and medialwards; medially it is smooth, and articulates with the navicular bone; laterally it is rough and continuous with the lateral surface. The *inferior surface* is oval, concave from side to side, convex from before backwards, so as to form a saddle-shaped surface for articulation with the base of the first metacarpal bone. The *dorsal surface* is rough. The *volar surface* is narrow and rough. At its upper part is a deep groove, running from above downwards; it transmits the tendon of the Flexor carpi radialis, and is bounded laterally by a ridge which affords attachment to the transverse carpal ligament, and gives origin to the Opponens pollicis, Abductor pollicis brevis and Flexor pollicis brevis. The *lateral surface* is broad and rough for the attachment of ligaments. On the *medial surface* are two facets; the upper, large and concave, articulates with the lesser multangular bone; the lower, small and oval, with the base of the second metacarpal bone.

THE LESSER MULTANGULAR BONE (OS MULTANGULUM MINUS) 4

The **lesser multangular** or **trapezoid bone** (fig. 389) is the smallest bone in the distal row. It may be known by its wedge-shaped form, the thick end of the wedge constituting the dorsal, the thin end the volar surface; and

FIG. 389.—The left lesser multangular bone.



by its having four articular facets separated by sharp edges. The *superior surface*, small, quadrilateral, and slightly concave, articulates with the navicular bone. The large *inferior surface* articulates with the proximal end of the second metacarpal bone; it is convex from side to side, concave from before

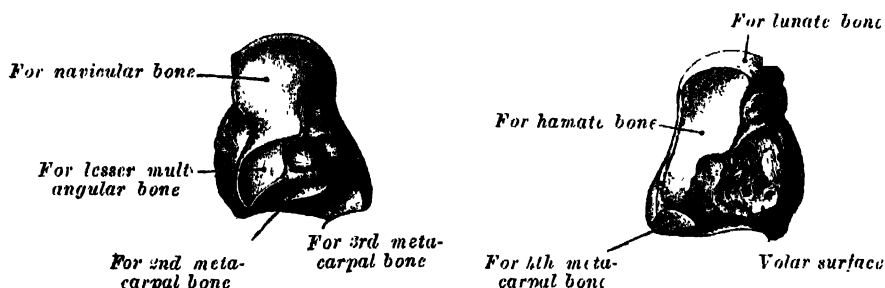
* R. H. Robbins, *Journal of Anatomy and Physiology*, vol. II.

backwards. The *dorsal* and *volar surfaces* are rough for the attachment of ligaments, the former being the larger. The *lateral surface* is convex, and articulates with the greater multangular bone. The *medial surface* is concave and smooth in front, for articulation with the capitate bone; rough behind for the attachment of an interosseous ligament.

THE CAPITATE BONE (OS CAPITATUM)

The capitate bone or os magnum (fig. 390) is the largest of the carpal bones, and occupies the centre of the wrist. It presents a rounded upper portion, the head, which is received into the concavity formed by the navicular and lunate bones; a constricted portion, the neck; and below this, the body. The

FIG. 390.—The left capitate bone.

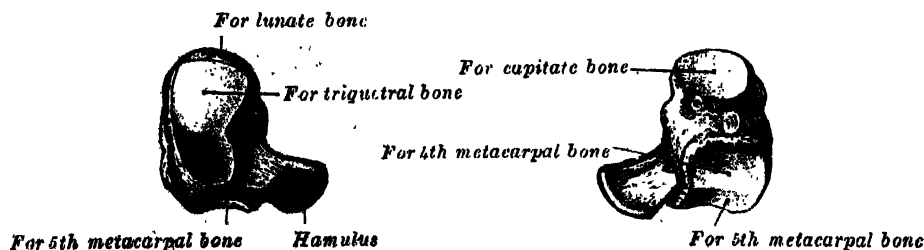


superior surface is round, smooth, and articulates with the lunate bone. The *inferior surface* is divided by two ridges into three facets, for articulation with the second, third, and fourth metacarpal bones, that for the third being the largest. The *dorsal surface* is broad and rough. The *volar surface* is narrow, projecting and rough, for the attachment of ligaments and the oblique part of the *Adductor pollicis*. The *lateral surface* articulates, by a small facet at its anterior inferior angle, with the lesser multangular bone; behind this facet is a rough depression for the attachment of an interosseous ligament. Above this is a deep, rough groove, forming part of the neck, and serving for the attachment of ligaments; it is bounded superiorly by a smooth, convex surface, for articulation with the navicular bone. The *medial surface* articulates with the hamate bone by a smooth, oblong facet, which occupies the posterior and superior parts of this surface; its anterior part is rough for the attachment of an interosseous ligament.

THE HAMATE BONE (OS HAMATUM) S-

The hamate or unciform bone (fig. 391) may be readily distinguished by its wedge-shaped form, and the hook-like process which projects from its volar

FIG. 391.—The left hamate bone.



surface. It is situated at the medial and lower angle of the carpus, with its base directed downwards, and its apex upwards and lateralwards. The *superior*

surface, the apex of the wedge, is narrow, convex, smooth, and articulates with the lunate bone. The *inferior surface* articulates with the fourth and fifth metacarpal bones, by concave facets which are separated by a slight ridge. The *dorsal surface* is triangular, and rough for ligaments. From the lower and medial part of the *volar surface* a curved, hook-like process, the *hamulus*, is directed forwards and lateralwards. This process gives attachment, by its apex, to the transverse carpal ligament and the Flexor carpi ulnaris; by its medial surface to the Flexor brevis and Opponens digiti quinti; its lateral side is grooved for the passage of the Flexor tendons into the palm of the hand. The *medial surface* articulates with the triquetral bone by an oblong, obliquely cut facet. The upper and posterior part of the *lateral surface* articulates with the capitate bone; the rest of the surface is rough for the attachment of ligaments.

THE METACARPUS

The **metacarpus** consists of five cylindrical bones which are numbered from the lateral side (ossa metacarpalia I-V); each consists of a body and two extremities.

COMMON CHARACTERISTICS OF THE METACARPAL BONES

The **body** is prismoid in form, and curved, so as to be convex longitudinally behind, concave in front. It has three surfaces: medial, lateral, and dorsal. The *medial* and *lateral surfaces* are concave, for the attachment of the Interossei, and separated from one another by a prominent anterior ridge. The *dorsal surface* presents in its distal two-thirds a smooth, triangular, flattened area which is covered, in the recent state, by the tendons of the Extensor muscles. This surface is bounded by two lines, which commence in small tubercles situated at the sides of the digital extremity, and converge and meet some distance above the centre of the bone to form a ridge which is continued to the carpal extremity. This ridge separates two sloping surfaces for the attachment of the Interossei dorsales. To the tubercles at the digital extremities are attached the collateral ligaments of the metacarpophalangeal joints.

The **base** or **carpal extremity** is of a cuboidal form, and broader behind than in front: it articulates with the carpus, and with the adjoining metacarpal bones; its *dorsal* and *volar surfaces* are rough, for the attachment of ligaments.

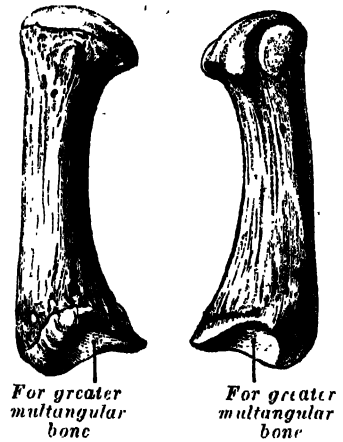
The **head** or **digital extremity** presents an oblong surface markedly convex from before backwards, less so transversely; it articulates with the proximal phalanx. It is broader, and extends farther upwards, on the volar than on the dorsal surface, and is longer in the anteroposterior than in the transverse diameter. On either side of the head is a deep depression, and behind this a tubercle for the attachment of the collateral ligament of the metacarpophalangeal joint. The *dorsal surface*, broad and flat, supports the Extensor tendons; the *volar surface* is grooved for the Flexor tendons, and marked on either side by an articular eminence continuous with the terminal articular surface.

CHARACTERISTICS OF THE INDIVIDUAL METACARPAL BONES 2

The **first metacarpal bone** (fig. 392) is shorter and stouter than the others, diverges to a greater degree from the carpus, and its volar surface is directed medialwards. The *body* is flattened and broad on its dorsal surface, and does not present the ridge which is found on the other metacarpal bones; its volar surface is concave from above downwards. The *Opponens pollicis* is inserted into its radial border; the lateral head of the first Interosseus dorsalis arises from its ulnar border. The *base* presents a concavoconvex surface, for articulation with the greater multangular bone; it has no facets on its sides, but on its radial side is a tubercle for the insertion of the Abductor

pollicis longus. The head is less convex than the heads of the other metacarpal bones, and is broader from side to side than from before backwards. On its volar surface are two articular eminences, of which the lateral is the larger, for the two sesamoid bones in the tendons of the *Flexor pollicis brevis*.

FIG. 392.—The first left metacarpal bone.



The second metacarpal bone (fig. 393) is the longest, and its base the largest, of the four remaining bones. Its base is prolonged upwards and medialwards, forming a prominent ridge. It presents four articular facets: three on the upper surface and one on the lateral side. Of the facets on the upper surface the intermediate is the largest and is concave from side to side, convex from before backwards for articulation with the lesser multangular bone; the lateral is small, flat and oval for articulation with the greater multangular bone; the medial, on the summit of the ridge, is long and narrow for articulation with the capitate bone. The facet on the medial side articulates with the third metacarpal bone. The *Extensor carpi radialis longus* is inserted on the lateral part of the dorsal surface, and the *Flexor carpi radialis* on the volar surface, of the base.

The third metacarpal bone (fig. 394) is a little smaller than the second. The dorsal part of its base presents on its radial side a pyramidal eminence, the *styloid process*, which extends upwards behind the capitate bone; immediately distal to this is a rough surface for the attachment of the *Extensor carpi*

FIG. 393.—The second left metacarpal bone.

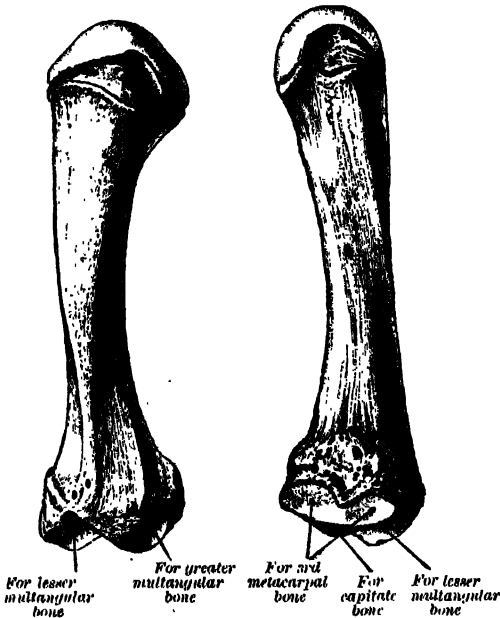
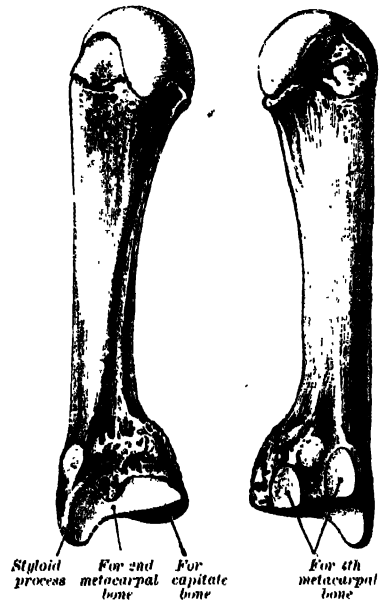


FIG. 394.—The third left metacarpal bone.



radialis brevis. The carpal articular facet is concave behind, flat in front, and articulates with the capitate bone. On the radial side is a smooth, concave facet for articulation with the second metacarpal bone, and on the ulnar side two small oval facets for the fourth metacarpal bone.

The fourth metacarpal bone (fig. 395) is shorter than the third. Its base is small and quadrilateral; on its superior surface are two facets, a large medial one for articulation with the hamate bone, and a small one at the posterolateral

angle for the capitate bone. On the lateral side are two oval facets, for articulation with the third metacarpal bone; and on the medial side, a single concave facet, for the fifth metacarpal bone.

3 The fifth metacarpal bone (fig. 396) has two facets on its *base*; that on its superior surface is saddle-shaped, and articulates with the hamate bone; that on the lateral side articulates with the fourth metacarpal bone. On its medial side is a tubercle for the insertion of the tendon of the Extensor carpi ulnaris. The dorsal surface of the body is divided by an oblique ridge, which

FIG. 395.—The fourth left metacarpal bone.

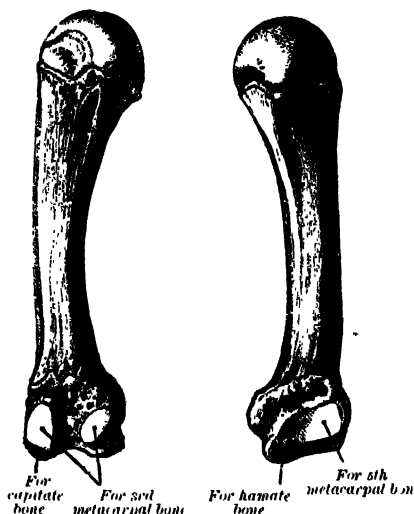
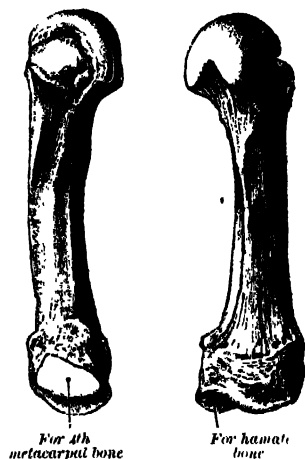


FIG. 396.—The fifth left metacarpal bone.



extends from near the ulnar side of the base to the radial side of the head. The lateral part of this surface serves for the attachment of the fourth Interosseus dorsalis; the medial part is smooth, triangular, and covered by the extensor tendons of the little finger.

THE PHALANXES (PHALANXES DIGITORUM MANUS)

The phalanges are fourteen in number, three for each finger, and two for the thumb. Each consists of a body and two extremities. The *body* tapers from above downwards, and its posterior surface is convex; its anterior surface is concave from above downwards, and flat from side to side; its sides are marked by rough ridges, which give attachment to the fibrous sheaths of the Flexor tendons. The *proximal extremities* of the bones of the first row present oval, concave articular surfaces, broader from side to side than from before backwards. On the *proximal extremity* of each of the bones of the second and third rows are two concavities separated by a median ridge. The *distal extremities* are smaller than the proximal, and each ends in two condyles separated by a shallow groove; the articular surface extends farther on the volar than on the dorsal surface, a condition best marked in the bones of the first row.

The *ungual phalanges* are convex on their dorsal, and flat on their volar surfaces; they are recognised by their small size, and by a roughened, elevated surface of a horseshoe form on the volar surface of the distal extremity of each which serves to support the sensitive pulp of the finger.

OSSIFICATION OF THE BONES OF THE HAND

The carpal bones are each ossified from a single centre, and ossification proceeds in the following order (fig. 397): in the capitate and hamate bones, during the first year, the former preceding the latter; in the triquetral bone, during the third year; in the lunate and greater multangular bones, during the fifth year, the former

preceding the latter ; in the navicular bone, during the sixth year ; in the lesser multangular bone, during the eighth year ; and in the pisiform bone, about the twelfth year.

Occasionally an additional bone, the *os centrale*, is found on the back of the carpus, lying between the navicular, lesser multangular, and capitate bones. During the second month of foetal life it is represented by a small cartilaginous nodule, which usually fuses with the cartilaginous navicular. Sometimes the styloid process of the third metacarpal bone is detached and forms an additional ossicle.

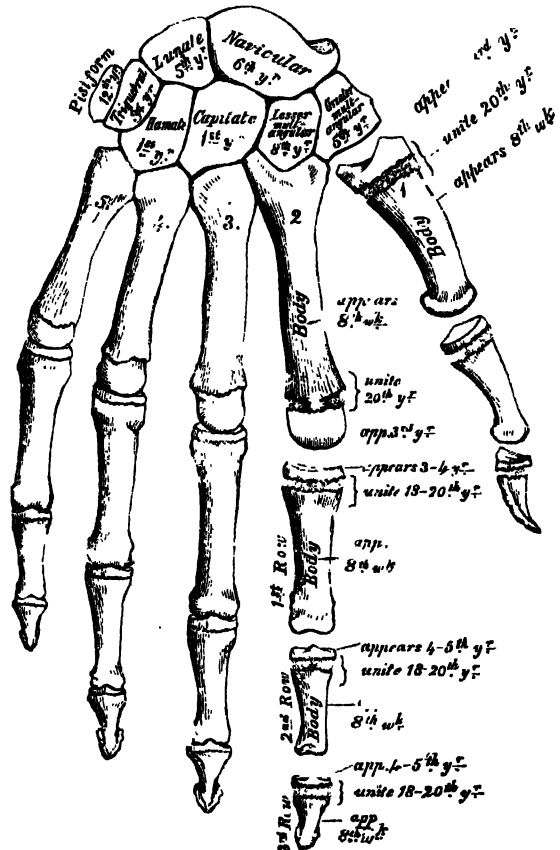
The **metacarpal bones** are each ossified from two centres ; one for the body and one for the head or distal end of each of the second, third, fourth and fifth bones ;

FIG. 397.—Plan of ossification of the bones of the hand.

CARPUS
One centre for each bone.
All cartilaginous at birth

METACARPALS OF FINGERS
Two centres for each bone :
One for body
One for head

PHALANGES
Two centres for each bone :
One for body
One for proximal extremity



one for the body and one for the base or proximal end of the first.* The first metacarpal bone is therefore ossified in the same manner as the phalanges, and this has led some anatomists to regard the thumb as being made up of three phalanges, and not of a metacarpal bone and two phalanges. Ossification begins in the middle of the body about the eighth or ninth week of foetal life, the centres for the second and third metacarpals being the first, and that for the first metacarpal the last, to appear ; about the third year the distal extremities of the metacarpals of the fingers, and the base of the metacarpal of the thumb, begin to ossify ; they unite with the bodies about the twentieth year.

The **phalanges** are each ossified from two centres ; one for the body, and one for the proximal extremity. Ossification begins in the body, about the eighth week of foetal life. Ossification of the proximal extremity commences in the bones of

* Allen Thomson (*Journal of Anatomy and Physiology*, vol. iii. 1869) pointed out that the first metacarpal bone is often developed from three centres ; that is to say, there is a separate centre for the distal end, forming a distinct epiphysis visible at the age of seven or eight years. He also stated that there are traces of a proximal epiphysis in the second metacarpal bone.

the first row between the third and fourth years, and a year later in those of the second and third rows. The two centres become united in each row between the eighteenth and twentieth years.

In the ungual phalanges the centres for the bodies appear at the distal extremities of the phalanges, instead of at the middle of the bodies, as in the other phalanges. Moreover, of all the bones of the hand, the ungual phalanges are the first to ossify.

Applied Anatomy.—The carpal bones are little liable to fracture except from extreme violence, when the parts are so comminuted as to necessitate amputation. Occasionally they are the seat of tuberculous disease. The metacarpal bones and the phalanges are sometimes broken from direct violence. There are two diseases of the metacarpal bones and phalanges which require special mention on account of their frequent occurrence. One is tuberculous dactylitis, consisting in a deposit of tuberculous material in the medullary canal, expansion of the bone, with subsequent caseation and necrosis. The other is chondroma, which is perhaps more commonly found in connexion with the metacarpal bones and phalanges than with any other bones. The tumours are usually multiple, and spring from beneath the periosteum about the epiphysal plate.

BONES OF THE INFERIOR EXTREMITY

THE HIP-BONE (OS COXÆ)

The **hip-bone** (os innominatum) (figs. 398, 399) is a large, flattened, irregularly shaped bone, constricted in the centre and expanded above and below. It articulates in front with the bone of the opposite side, and the two bones form the anterior and lateral walls of the pelvis. It consists of three parts, the ilium, ischium, and os pubis, which are distinct from each other in the young subject, but are fused in the adult; the union of the three parts takes place in and around a large cup-shaped articular cavity, the acetabulum, which is situated near the middle of the outer surface of the bone. The *ilium*, so called because it supports the flank, is the broad and expanded portion which extends upwards from the acetabulum. The *ischium* is the lowest and strongest portion of the bone; it proceeds downwards from the acetabulum, expands into a large tuberosity, and then curves forwards below a large aperture, the obturator foramen. The *os pubis* extends medialwards and downwards from the acetabulum and articulates in the middle line with the bone of the opposite side.

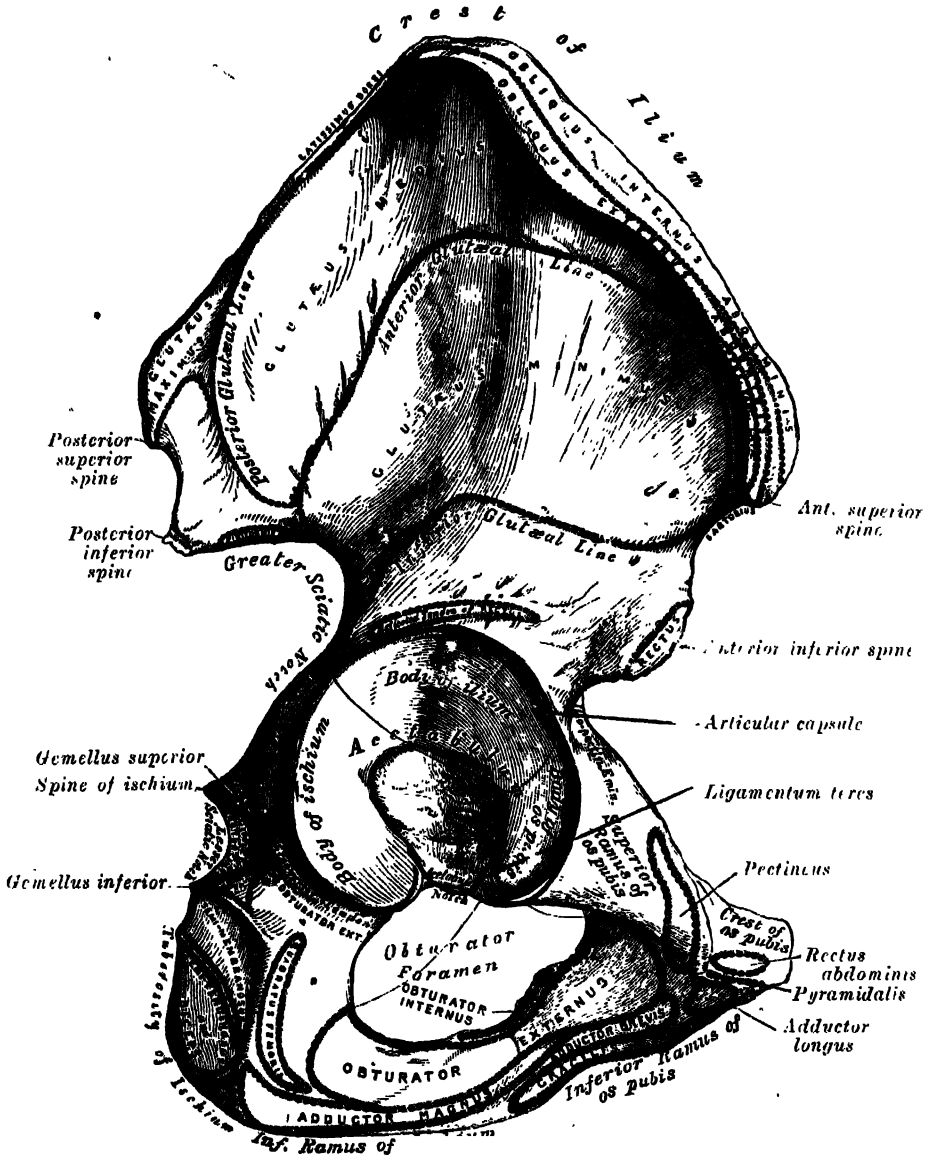
The *ilium* (os ilii) is divisible into two parts, the body and the ala; the separation is indicated on the internal surface by a curved line, the *arcuate line*, and on the external surface by the upper part of the margin of the acetabulum.

The **body** forms rather less than two-fifths of the acetabulum. Its *external surface* is partly articular, partly non-articular; the articular segment forms part of the lunate surface of the acetabulum, the non-articular portion contributes to the acetabular fossa. The *internal surface* of the body is part of the wall of the lesser pelvis; it gives origin to some fibres of the *Obturator internus* and is continuous below with the pelvic surfaces of the ischium and os pubis.

The **ala**, the large expanded portion, bounds the greater pelvis laterally. It has an external and an internal surface, a crest, and an anterior and a posterior border. The *external surface*, or *dorsum ilii* (fig. 398), is directed backwards and lateralwards behind, and lateralwards and downwards in front. It is smooth, convex in front, concave behind, and is bounded above by the crest, below by the upper border of the acetabulum, and in front and behind by the anterior and posterior borders. This surface is crossed by the posterior, anterior, and inferior gluteal lines. The *posterior gluteal line* (superior curved line), the shortest of the three, begins at the crest, about 5 cm. in front of its posterior extremity; it is distinctly marked above, but as it descends to the upper part of the greater sciatic notch, where it ends, it becomes less distinct, and is often lost. Behind this line is a narrow, semilunar surface, the upper part of which is rough and gives origin to a portion of the *Gluteus maximus*; the lower part is smooth, and has no muscular fibres attached to it. The *anterior gluteal*

line (middle curved line), the longest of the three, begins at the crest, about 4 cm. behind its anterior extremity, and, taking a curved direction backwards and downwards, ends at the upper part of the greater sciatic notch. A nutrient foramen is often seen near the middle of this line. The surface between the crest and the anterior and posterior glutæal lines, gives origin to the Glutæus

FIG. 398.—Right hip-bone. External surface.

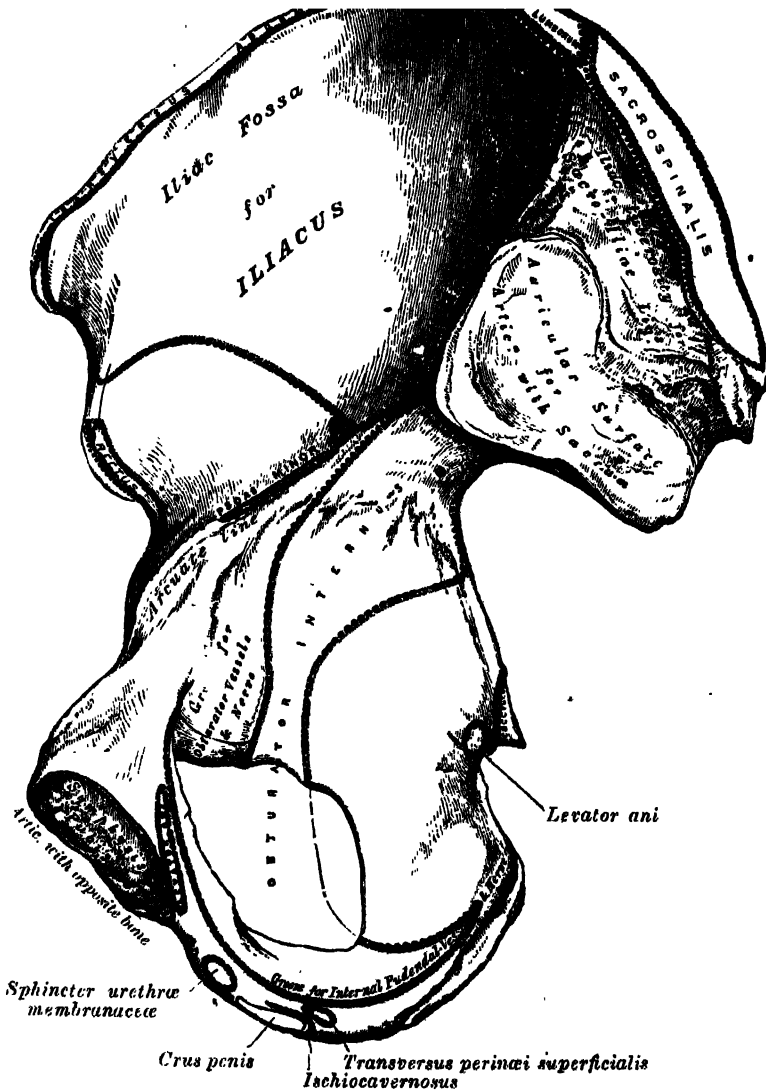


medius. The *inferior glutæal line* (inferior curved line), the least distinct, begins in front at the notch on the anterior border, and, curving backwards and downwards, ends near the middle of the greater sciatic notch; the Glutæus minimus takes origin between the anterior and inferior glutæal lines. From a rough, shallow groove immediately above the acetabulum, the reflected tendon of the Rectus femoris arises.

The *internal surface* (fig. 399) of the ala is bounded above by the crest; below by the arcuate line; in front and behind by the anterior and posterior borders. Its anterior part, smooth and concave, is termed the iliac fossa;

it gives origin to the *Iliacus*, and its posterior part is perforated by a nutrient canal; the tendon of the *Psoas minor* is inserted into the arcuate line. Behind the iliac fossa is a rough surface, divided into two portions, a superior and an inferior. The inferior portion or *auricular surface*, so called from its resemblance in shape to the auricula, is coated with cartilage in the recent state, and articulates with a similar surface on the side of the sacrum. The superior

FIG. 399.—Right hip-bone. Internal surface.



portion, known as the *iliac tuberosity*, is elevated and rough, for the attachment of the posterior sacro-iliac ligaments; it is continuous above and behind with the inner lip of the iliac crest, and here it gives origin to the *Sacrospinalis* and *Multifidus* muscles. Below and in front of the auricular surface is the *pre-auricular sulcus*, more commonly present and better marked in the female than in the male; the pelvic portion of the anterior sacro-iliac ligament is attached to this sulcus.

The crest of the ilium is convex in its general outline but is sinuously curved, being concave inwards in front, and outwards behind. It is thinner at the

centre than at the extremities, and ends in the anterior and posterior superior iliac spines. The surface of the crest is divided into external and internal lips, and an intermediate line; about 5 cm. behind the anterior superior iliac spine there is a prominent tubercle on the external lip. To the external lip are attached, from before backwards, the *Tensor fasciæ latæ*, *Obliquus externus abdominis*, and *Latissimus dorsi*, and along its whole length the *fascia lata*; to the intermediate line the *Obliquus internus abdominis*; to the internal lip, the *fascia iliaca*, the *Transversus abdominis*, *Quadratus lumborum*, *Sacrospinalis*, and *Iliacus*.

The anterior border of the ala is concave and presents two projections, separated by a notch. The upper projection, at the junction of the crest and anterior border, is called the *anterior superior iliac spine*; its outer border gives attachment to the *fascia lata* and the *Tensor fasciæ latæ*; its inner border, to the *Iliacus*; its extremity affords attachment to the *inguinal ligament*, and origin to the *Sartorius*. Beneath this spine is a notch from which the *Sartorius* takes origin and across which the *lateral femoral cutaneous nerve* passes. Below the notch is the *anterior inferior iliac spine*, which ends inferiorly in the upper lip of the acetabulum; it gives attachment to the straight tendon of the *Rectus femoris* and to the *iliofemoral ligament* of the hip-joint. Medial to the anterior inferior spine is a broad, shallow groove, over which the *Iliacus* descends into the thigh. This groove is bounded medially by the *iliopectineal eminence*, which marks the union of the ilium and the os pubis.

The posterior border of the ala, shorter than the anterior, also presents two projections, the *posterior superior* and *posterior inferior iliac spines*, separated by a notch. The former serves for the attachment of the long posterior sacro-iliac ligament and the *Multifidus* muscle; the latter corresponds with the posterior end of the auricular surface. Below the posterior inferior spine is a deep notch, the *greater sciatic notch*.

The ischium (os ischii) forms the lower and posterior part of the hip-bone. It is divisible into a body and a superior and an inferior ramus.

The body enters into and constitutes a little more than two-fifths of the acetabulum. Its *external surface* forms part of the lunate surface of the acetabulum and a portion of the acetabular fossa. Its *internal surface* is part of the wall of the lesser pelvis, and gives origin to some fibres of the *Obturator internus*. Its *posterior surface* is convex, and covered by the *Piriformis* muscle. Its *antero-inferior border* is thin, and forms part of the boundary of the obturator foramen; it ends above at the acetabular notch, where it frequently presents a small tubercle, the *posterior obturator tubercle*. Its *lateral border* forms the posterior part of the rim of the acetabulum; from its *posterior border* a pointed triangular eminence, the *ischial spine*, extends backwards and medialwards. The external surface of this spine gives attachment to the *Gemellus superior*; its internal surface to the *Coccygeus*, *Levator ani*, and the *pelvic fascia*; its pointed extremity to the *sacrospinous ligament*. Above the spine is the *greater sciatic notch*, converted into a foramen by the *sacrospinous ligament*; this foramen transmits from the pelvis the *Piriformis muscle*, the superior and inferior gluteal vessels and nerves, the sciatic and posterior femoral cutaneous nerves, the internal pudendal vessels and pudendal nerve, and the nerves to the *Obturator internus* and *Quadratus femoris*. Of these, the superior gluteal vessels and nerve emerge above the *Piriformis*, the other structures below it. Below the spine is the *lesser sciatic notch*; it is converted into a foramen by the *sacrospinous* and *sacrospinous ligaments*, and transmits the tendon of the *Obturator internus*, the nerve which supplies that muscle, and the internal pudendal vessels and pudendal nerve.

The superior ramus projects downwards and backwards from the body and has three surfaces: external, internal, and posterior. The *external surface* is quadrilateral in shape. It is bounded above by a groove which lodges the tendon of the *Obturator externus*; below, it is continuous with the external surface of the inferior ramus; in front, it is limited by the posterior margin of the obturator foramen; behind, a prominent margin separates it from the posterior surface. In front of this margin the external surface gives origin to the *Quadratus femoris*, and to some of the fibres of the *Obturator externus*; its lower part gives origin to part of the *Adductor magnus*. The *internal surface* forms part of the bony wall of the lesser pelvis. In front it is limited

by the posterior margin of the obturator foramen. Below and behind, it is bounded by a sharp ridge which gives attachment to the *falciform process* of the sacrotuberous ligament; more anteriorly it gives origin to the *Transversus perinæi superficialis* and *Ischiocavernosus*.

Posteriorly the superior ramus forms a large swelling, the *tuberosity of the ischium*, which is divided into two portions: a lower, rough, somewhat triangular part, and an upper, smooth, quadrilateral portion. The lower portion is subdivided by a prominent longitudinal ridge into two parts; the lateral gives attachment to the Adductor magnus, the medial to the sacrotuberous ligament. The upper portion is subdivided into two areas by an oblique ridge which runs downwards and lateralwards; from the upper and lateral area the Semimembranosus arises; from the lower and medial, the long head of the Biceps femoris and the Semitendinosus.

The *inferior ramus* is the thin, flattened part of the ischium, which passes forwards from the superior ramus, and joins the inferior ramus of the os pubis, the junction being indicated by a raised line. Its *outer surface* is uneven for the origin of the Obturator externus and some of the fibres of the Adductor magnus; its *inner surface* forms part of the anterior wall of the pelvis, and gives attachment to the Sphincter urethræ membranaceæ. Its *lower border* is thick, rough, slightly everted, forms part of the outlet of the pelvis, and presents two slight ridges and an intervening space. The ridges are continuous with similar ones on the inferior ramus of the os pubis; to the outer is attached the deep layer of the superficial perinæal fascia (fascia of Colles), and to the inner the inferior fascia of the urogenital diaphragm. When traced backwards these two ridges join just behind the point of origin of the Transversus perinæi superficialis: to the intervening space, just in front of the point of junction of the ridges, the Transversus perinæi superficialis is attached, and in front of this the Ischiocavernosus and the crus penis vel clitoridis. Its *upper border* is thin and sharp, and forms part of the medial margin of the obturator foramen.

The *os pubis*, the anterior part of the hip-bone, is divisible into a body, and a superior and an inferior ramus.

The *body* forms one-half of the acetabulum, contributing by its *external surface* both to the *lunate surface* and to the acetabular fossa. Its *internal surface* enters into the formation of the wall of the lesser pelvis.

The *superior ramus* extends on the body to the median plane, where it articulates with its fellow of the opposite side. It is conveniently described in two portions, viz. a medial flattened part and a narrow lateral prismoid portion.

The *medial portion* of the superior ramus, formerly described as the body of the os pubis, is somewhat quadrilateral in shape, and presents for examination two surfaces and three borders. The *anterior surface* is rough, directed downwards and lateralwards, and serves for the origin of various muscles. The Adductor longus arises from the upper and medial angle, immediately below the crest; lower down, the Obturator externus, the Adductor brevis, and the upper part of the Gracilis take origin. The *posterior surface*, convex from above downwards, concave from side to side, is smooth, and forms part of the anterior wall of the pelvis. It gives origin to parts of the Levator ani and Obturator internus, and attachment to the puboprostatic ligaments and to a few muscular fibres prolonged from the bladder. The *upper border* presents a prominent tubercle, the *pubic tubercle* (pubic spine), which projects forwards; the inferior crus of the subcutaneous inguinal ring (external abdominal ring), and the inguinal ligament (Poupart's ligament) are attached to it. Passing upwards and lateralwards from the pubic tubercle is a well-defined ridge, the *pecten pubis*, which forms a part of the brim of the lesser pelvis; to it are attached a portion of the inguinal falx (conjoined tendon of Obliquus internus and Transversus), the lacunar ligament (Gimbernat's ligament), and the reflected inguinal ligament (triangular fascia). Medial to the pubic tubercle is the *crest*, which extends from the tubercle to the medial border of the bone; it affords attachment to the inguinal falx, and to the Rectus abdominis and Pyramidalis. The point of junction of the crest with the medial border of the bone is called the *angle*; to it, as well as to the symphysis, the superior crus of the subcutaneous inguinal ring is attached. The *medial border* is articular; it is oval, and is

marked by eight or nine transverse ridges, or a series of nipple-like processes arranged in rows; they serve for the attachment of a thin layer of cartilage, which is fixed to that of the opposite pubic bone by the *interpubic fibrocartilaginous lamina*. The *lateral border* presents a sharp margin, the *obturator crest*, which forms part of the circumference of the obturator foramen and affords attachment to the *obturator membrane*.

The *lateral portion* of the superior ramus has three surfaces: superior, inferior, and posterior; between the superior and posterior surfaces is a continuation of the pecten pubis, already mentioned as commencing at the pubic tubercle. The *superior surface*, in front of this line, is triangular in form, wider laterally than medially, and covered by the Pectineus. It is bounded laterally by a rough eminence, the *iliopectineal eminence*, which indicates the junction of the ilium and os pubis, and below by a prominent ridge which extends from the anterior margin of the acetabular notch to the pubic tubercle. The *inferior surface* forms the upper boundary of the obturator foramen, and presents, laterally, a broad, deep, groove, the *obturator groove*, for the passage of the obturator vessels and nerve; and medially, a sharp margin which is continuous below with the obturator crest; it gives attachment to the obturator membrane. The *posterior surface* constitutes part of the anterior boundary of the lesser pelvis. It is smooth, convex from above downwards, and affords origin to some fibres of the Obturator internus.

The *inferior ramus* is thin and flattened. It passes lateralwards and downwards from the medial part of the superior ramus, narrows as it descends and joins with the inferior ramus of the ischium below the obturator foramen. Its *anterior surface* is rough for the origin of muscles—the Gracilis along its medial border, a portion of the Obturator externus near the obturator foramen, and between these two muscles, the Adductores brevis and magnus, the former being the more medial. The *posterior surface* is smooth, and gives origin to the Obturator internus, and, close to the medial margin, to the Sphincter urethræ membranaceæ. The *medial border* is thick, rough, and everted, especially in females. It presents two ridges, separated by an intervening space. The ridges extend downwards, and are continuous with similar ridges on the inferior ramus of the ischium; to the medial is reached the superficial perineal fascia (fascia of Colles), and to the lateral the inferior fascia of the urogenital diaphragm. The *lateral border* is thin and sharp, forms part of the circumference of the obturator foramen, and gives attachment to the obturator membrane.

The *acetabulum* is a deep, cup-shaped, hemispherical depression, which looks downwards, lateralwards, and forwards. It is formed medially by the os pubis, above by the ilium, laterally, and below by the ischium; a little less than two-fifths is contributed by the ilium, a little more than two-fifths by the ischium, and one-fifth by the os pubis. It is surrounded by a prominent, uneven rim, which is thick and strong above and serves for the attachment of the glenoidal labrum (cylindroid growth), which contracts the orifice of the acetabulum, and deepens the surface for articulation. It presents below, a deep notch, the *acetabular notch*, which is continuous with a circular non-articular depression, the *acetabular fossa*, at the bottom of the cavity; this fossa is perforated by apertures for vessels, and lodges a mass of fat. The notch is converted into a foramen by the transverse acetabular ligament, and through the foramen nutrient vessels and nerves enter the joint; the margins of the notch serve for the attachment of the ligamentum teres. The rest of the acetabulum is formed by a curved articular surface, the *lunate surface*, for articulation with the head of the femur.

The *obturator foramen* is an aperture between the ischium and os pubis. In the male it is large and of an oval form, its longest diameter slanting obliquely from before backwards; in the female it is smaller, and more triangular. It is bounded by a thin, uneven margin, to which the obturator membrane is attached, and presents, superiorly, a deep groove, the *obturator groove*, which runs downwards and medialwards from the pelvis. This groove is converted into a canal by a ligamentous band, a specialised part of the obturator membrane, attached to two tubercles: one, the *posterior obturator tubercle* on the anteroinferior border of the ischium, just below the acetabular notch; the other, the *anterior obturator tubercle*, on the obturator crest of the superior

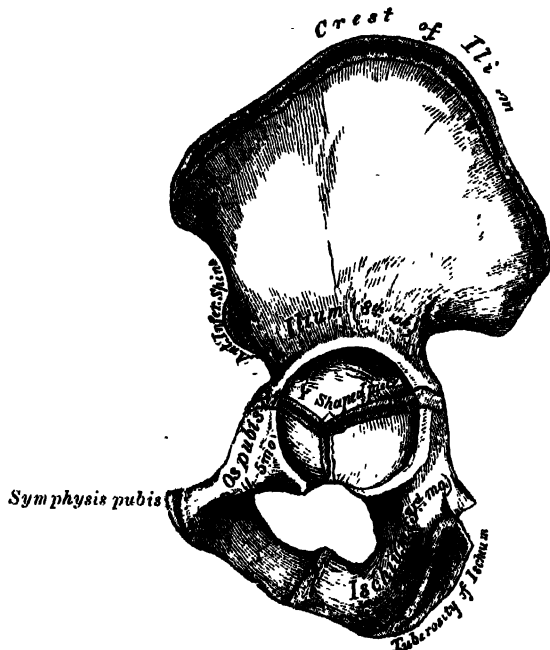
ramus of the os pubis. Through the canal the obturator vessels and nerve pass out of the pelvis.

Structure.—The thicker parts of the hip-bone consist of spongy substance, enclosed between two layers of compact bone; the thinner parts, as at the bottom of the acetabulum and centre of the iliac fossa, are usually semitransparent, and composed entirely of compact bone.

Ossification (fig. 400).—The hip-bone is ossified from eight centres: three primary, one each for the ilium, ischium, and os pubis; and five secondary, one each for the crest of the ilium, the anterior inferior iliac spine (said to occur more frequently in the male than in the female), the tuberosity of the ischium, the pubic symphysis (more frequent in the female than in the male), and one or more for the Y-shaped

FIG. 400.—Plan of ossification of the hip-bone.

By eight centres { Three primary (ilium, ischium, and os pubis)
Five secondary



The three primary centres unite through the Y-shaped piece about puberty.
Secondary centres appear about puberty, and unite about 25th year.

piece at the bottom of the acetabulum. The centres appear in the following order: in the ilium, immediately above the greater sciatic notch, about the eighth or ninth week of foetal life; in the superior ramus of the ischium, about the third month; in the superior ramus of the os pubis, between the fourth and fifth months. At birth, the iliac crest, the greater part of the acetabulum, the ischial tuberosity, and the inferior rami of the ischium and os pubis are cartilaginous. By the seventh or eighth year, the inferior rami of the os pubis and ischium are almost completely united by bone. By the twelfth year, the three primary centres have extended their growth into the bottom of the acetabulum, and are there separated from each other by a Y-shaped portion of cartilage, which now presents traces of ossification, often by two or more centres. One of these, the *os acetabuli*, forms the pubic part of the acetabulum and fuses with the main parts of the bone about puberty. The ilium and ischium then become joined, and lastly the os pubis and ischium, through the intervention of this Y-shaped portion. At about the age of puberty, ossification takes place in each of the remaining portions, and they join with the rest of the bone between the twentieth and twenty-fifth years. Separate centres are frequently found for the tubercle, crest and angle of the os pubis, and the spine of the ischium.

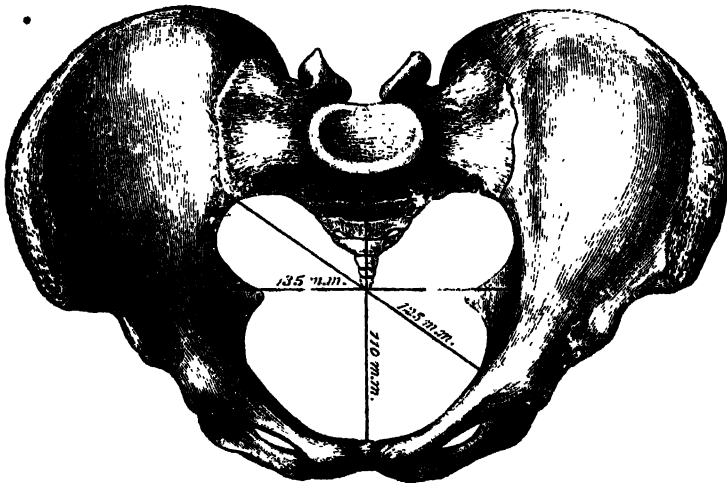
THE PELVIS

The **pelvis**, so called from its resemblance to a basin, is a massive bony ring, interposed between the movable segments of the vertebral column which it supports, and the lower limbs upon which it rests; it is composed of the two hip-bones laterally and in front, and the sacrum and coccyx behind. It is divided into the greater and the lesser pelvis by an oblique plane passing through the prominence of the sacrum behind, the arcuate line and pecten pubis laterally, and the upper margin of the symphysis pubis in front. The circumference of this plane is termed the *linea terminalis* or *pelvic brim*.

The **greater pelvis** (*pelvis major*), the expanded portion of the cavity above and in front of the pelvic brim, is formed on either side by the ilium and the ala of the sacrum.

The **lesser pelvis** (*pelvis minor*) is that part of the pelvic cavity which lies below and behind the pelvic brim. Its bony walls are more complete than

FIG. 401.—Diameters of superior aperture of lesser pelvis (female).



those of the greater pelvis. It possesses an inlet bounded by the superior circumference, an outlet bounded by the inferior circumference, and a cavity.

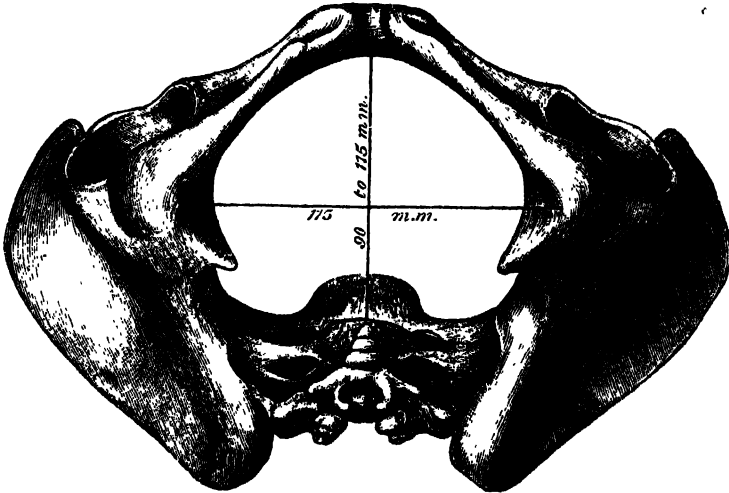
The *superior circumference* forms the brim of the pelvis, the included space being called the *superior aperture* or *inlet* (fig. 401). The superior aperture is somewhat heart-shaped, obtusely pointed in front, diverging on either side, and encroached upon behind by the forward projection of the promontory of the sacrum. It has three principal diameters: anteroposterior, transverse, and oblique. The *anteroposterior* or *conjugate diameter* extends from the sacrovertebral angle to the symphysis pubis: its average measurement is about 110 mm. in the female. The *transverse diameter* extends from the middle of the brim on one side to the same point on the opposite side; its average measurement is about 135 mm. in the female. The *oblique diameter* extends from the iliopectineal eminence to the opposite sacroiliac articulation; its average measurement is about 125 mm. in the female.

The *cavity* of the lesser pelvis is bounded in front and below by the pubic rami and symphysis; above and behind, by the pelvic surfaces of the sacrum and coccyx; laterally by a smooth, quadrangular area of bone, formed by the inner surfaces of the body and superior ramus of the ischium and of the body of the ilium. From this description, it will be seen that the cavity of the lesser pelvis is a short, curved canal, considerably deeper behind than in front. It contains, in the recent subject, the sigmoid (pelvic) colon, rectum, bladder, and some of the organs of generation. The rectum is placed at the

back of the pelvis, in the curve of the sacrum and coccyx ; the urinary bladder is in front, behind the pubic symphysis. In the female, the uterus and vagina are placed between the rectum and the urinary bladder.

The *lower circumference* of the pelvis is very irregular ; the space enclosed by it is named the *inferior aperture* or *outlet* (fig. 402), and is bounded behind by the apex of the coccyx, and laterally by the ischial tuberosities. These eminences are separated by three notches : one in front, the *pubic arch*, formed by the convergence of the inferior rami of the ischium and os pubis on either side. The other notches, one on either side, are formed by the sacrum and coccyx behind, the ischium in front, and the ilium above : they are called the *sciatic notches* ; in the natural state they are converted into foramina by the sacrotuberous and sacrospinous ligaments. When the ligaments are present, the inferior aperture of the pelvis is lozenge-shaped, and is bounded, in front, by the arcuate pubic ligament and the inferior rami of the ossa pubis and ischia ; laterally, by the ischial tuberosities ; behind, by the sacrotuberous ligaments and the tip of the coccyx.

FIG. 402.—Diameters of inferior aperture of lesser pelvis (female).



The *anteroposterior diameter* of the inferior aperture of the pelvis extends from the apex of the coccyx to the lower part of the pubic symphysis ; its measurement is from 90 to 115 mm. in the female. It varies with the length of the coccyx, and is capable of increase or diminution, on account of the mobility of that bone. The *transverse diameter*, measured between the posterior parts of the ischial tuberosities, is about 115 mm. in the female.*

Axes (fig. 403).—A line at right angles to the plane of the superior aperture at its centre would, if prolonged, pass through the umbilicus above and the middle of the coccyx below : the axis of the superior aperture is therefore directed downwards and backwards. The axis of the inferior aperture, produced upwards, would touch the base of the sacrum, and is directed downwards and slightly backwards. The axis of the cavity—i.e. an axis at right angles to a series of planes between those of the superior and inferior apertures—is curved like the cavity itself : this curve is parallel to that of the sacrum and coccyx, and its extremities are indicated by the central points of the superior and inferior apertures.

Position of the pelvis (fig. 403).—In the erect posture, the pelvis is placed obliquely with regard to the trunk : the plane of the superior aperture forms with the horizontal an angle of from 50° to 60°, and that of the inferior

* The measurements of the pelvis given above are fairly accurate, but different figures are given by various authors, no doubt due mainly to differences in the physique and stature of the population from whom the measurements have been taken.

aperture one of about 15° . The pelvic surface of the symphysis pubis looks upwards and backwards, the concavity of the sacrum and coccyx downwards and forwards. The position of the pelvis in the erect posture may be indicated by holding it so that the anterior superior iliac spines and the front of the top of the symphysis pubis are in the same vertical plane.

Differences between the male and female pelvises.—The female pelvis (fig. 405) is distinguished from that of the male (fig. 404) by its bones being more delicate and its depth less. The whole pelvis is less massive, and its muscular impressions are not so marked. The ilia are larger, their posterior borders are more rounded and less vertical, and the anterior iliac spines more widely separated; hence the greater lateral prominence of the hips. The superior aperture of the lesser pelvis is larger in the female than in the male; it is more nearly circular, and its obliquity is greater. The cavity is shallower and wider; the sacrum is shorter, wider, and its upper part is less curved; the obturator foramina are triangular in shape and are smaller in size than in the male. The inferior aperture is larger and the coccyx more movable. The pre-auricular sulci are more commonly present and better marked. The sciatic notches are wider and shallower, and the spines of the ischia project less inwards. The acetabula are wider apart, smaller and look

FIG. 403.—Median sagittal section of pelvis.

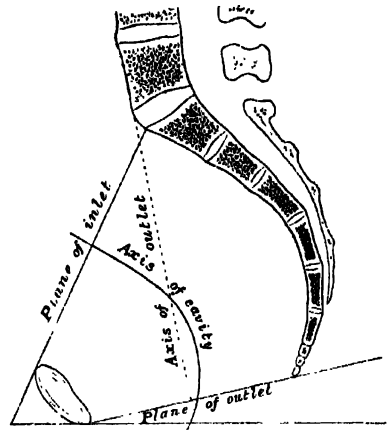
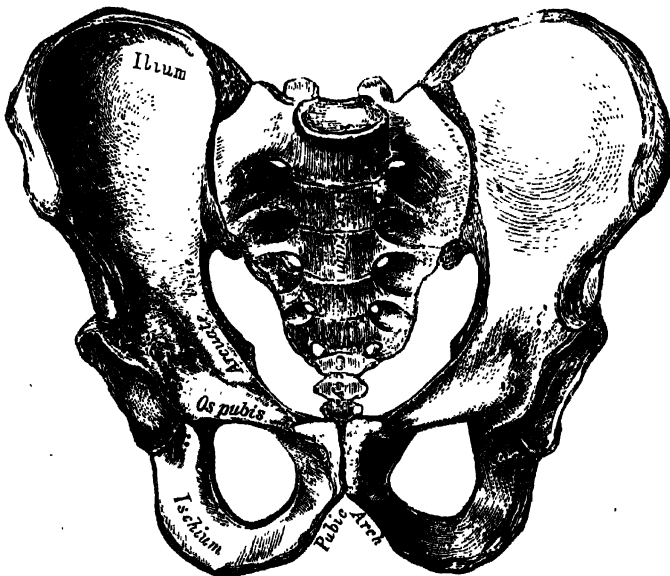


FIG. 404.—Male pelvis.



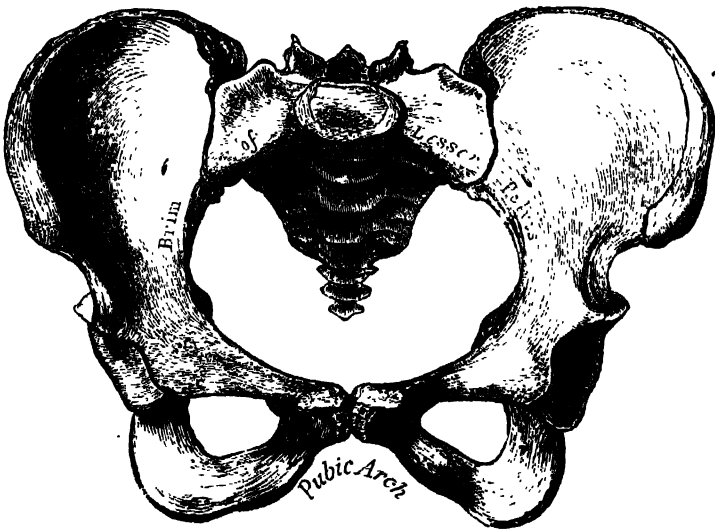
more distinctly forwards (Derry *). The ischial tuberosities are also wider apart, and are more everted. The depth of the pubic symphysis is less, and the pubic arch is wider and more rounded than in the male, where it is an

* *Journal of Anatomy and Physiology*, vol. xliii.

angle rather than an arch. The auricular surfaces for articulation with the sacrum usually involve only two vertebræ, whereas in the male they extend over two and a half or three vertebræ.

The size of the pelvis varies not only in the two sexes, but also in different members of the same sex, and does not appear to be influenced in any way by the height of the individual. Women of short stature, as a rule, have broad pelves. Occasionally the pelvis is contracted in all its dimensions, and its diameters may be as much as 12·5 mm. less than the average, and this even in well-formed women of average height. The principal divergences, however, are found at the superior aperture, and affect the relation of the anteroposterior to the transverse diameter. Thus the superior aperture may be elliptical either in a transverse or an anteroposterior direction, the transverse diameter in the former, and the anteroposterior in the latter, greatly exceeding the other diameters; in other instances it is almost circular.

FIG. 405.—Female pelvis.



In the *fœtus*, and for several years after birth, the pelvis is small in proportion to that of the adult, and the projection of the sacrovertebral angle less marked. The characteristic differences between the male and female pelves are distinctly indicated as early as the fourth month of foetal life

Applied Anatomy.—There is arrest of development in the bones of the pelvis in cases of extroversion of the bladder; the anterior part of the pelvic girdle is deficient, the superior rami of the pubic bones are imperfectly developed, and the symphysis is absent. The pubic bones are separated to the extent of from two to four inches, the superior rami shortened and directed forwards, and the obturator foramina diminished in size, narrowed, and turned outwards. The iliac bones are straightened out more than normal. The sacrum is very peculiar. The lateral curve, instead of being concave, is flattened out or even convex, with the iliosacral facets turned more outward than normal, while the vertical curve is straightened.*

Fractures of the pelvis are divided into those of the greater and those of the lesser pelvis. Fractures of the greater pelvis vary in extent; a small portion of the crest may be broken, or one of the spinous processes may be torn off, or the bone may be extensively comminuted. This latter accident is the result of some crushing violence, and may be complicated with fracture of the lesser pelvis. These cases may be accompanied by injury to the intestine as it lies in the hollow of the bone, or to the iliac vessels as they course along the margin of the lesser pelvis. A fracture of the lesser pelvis generally occurs through the superior ramus of the os pubis and the inferior ramus of the ischium, as these are the weakest parts of the bony ring, and may be caused either by crushing violence applied in an anteroposterior direction, when the fracture occurs from direct

* Wood. *Heath's Dictionary of Practical Surgery*, i. 426.

force, or by compression laterally, when the acetabula are pressed together and the bone gives way in the same place from indirect violence. Sometimes both sides of the pelvis are fractured, and it is in these cases that the contained viscera are likely to be injured: the urethra, the bladder, the rectum, the small intestines, the vagina, and even the uterus, have all been lacerated by displaced fragments. Fractures of the acetabulum are occasionally met with: either a portion of the rim may be broken off, or a fracture may take place through the bottom of the cavity, and the head of the femur be driven into the pelvic cavity. Separation of the Y-shaped cartilage at the bottom of the acetabulum may also occur in the young subject, splitting the bone into its three portions.

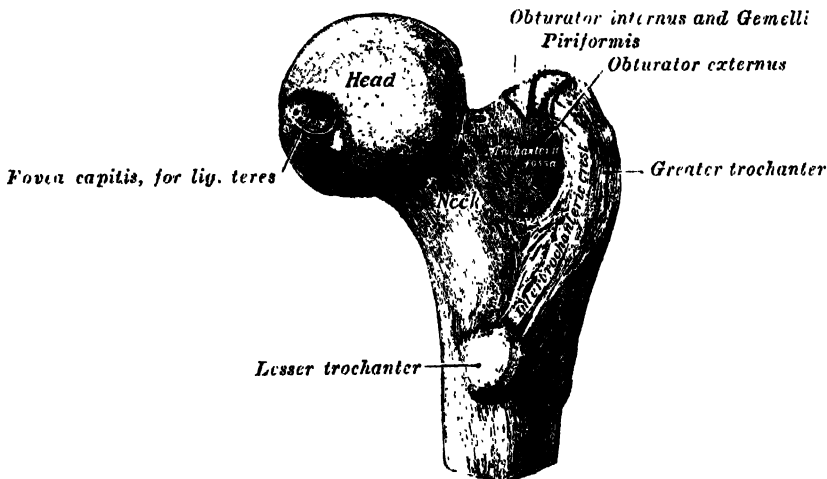
The coccyx is not infrequently displaced forwards to nearly a right angle with the sacrum by a kick or by a fall backwards. The condition is attended with great pain in walking and on making any expiratory effort, such as coughing, defæcation, etc., because the Coccygei and Levatores ani which form the pelvic diaphragm are attached to this bone. Such injuries often give rise to severe persistent pain, which is exceedingly intractable and difficult of cure. The condition is known as *coccygodynia*, and for its relief removal of the coccyx has been practised.

The pelvic bones often undergo important deformity in *rickets*, the effects of which in the adult woman may seriously interfere with child-bearing, demanding the premature induction of labour at a time when the fœtus will not yet be too large for delivery through the contracted or deformed pelvis. The deformity is due mainly to the weight of the trunk, which presses on the sacrovertebral angle and greatly increases it, so that the anteroposterior diameter of the pelvis is diminished, and may measure as little as 40 mm., the entrance into the pelvis becoming reniform. In other cases all the pelvic bones give way, so that a general diminution in all the diameters of the pelvis results, the pelvic entrance becoming triangular or asymmetrical. If the pubic symphysis be forced forwards, the rickety pelvis may even come to resemble closely the deformed pelvis of *osteomalacia*; in this disease the weight of the trunk causes an increase in the sacrovertebral angle, and a lessening of the anteroposterior diameter of the superior aperture, and at the same time the pressure of the heads of the femora on the acetabula causes these cavities, with the adjacent bone, to be pushed upwards and backwards, so that the oblique diameters of the pelvis are also diminished, and the cavity of the pelvis assumes a triradiate shape, with the symphysis pubis pushed forwards.

THE FEMUR

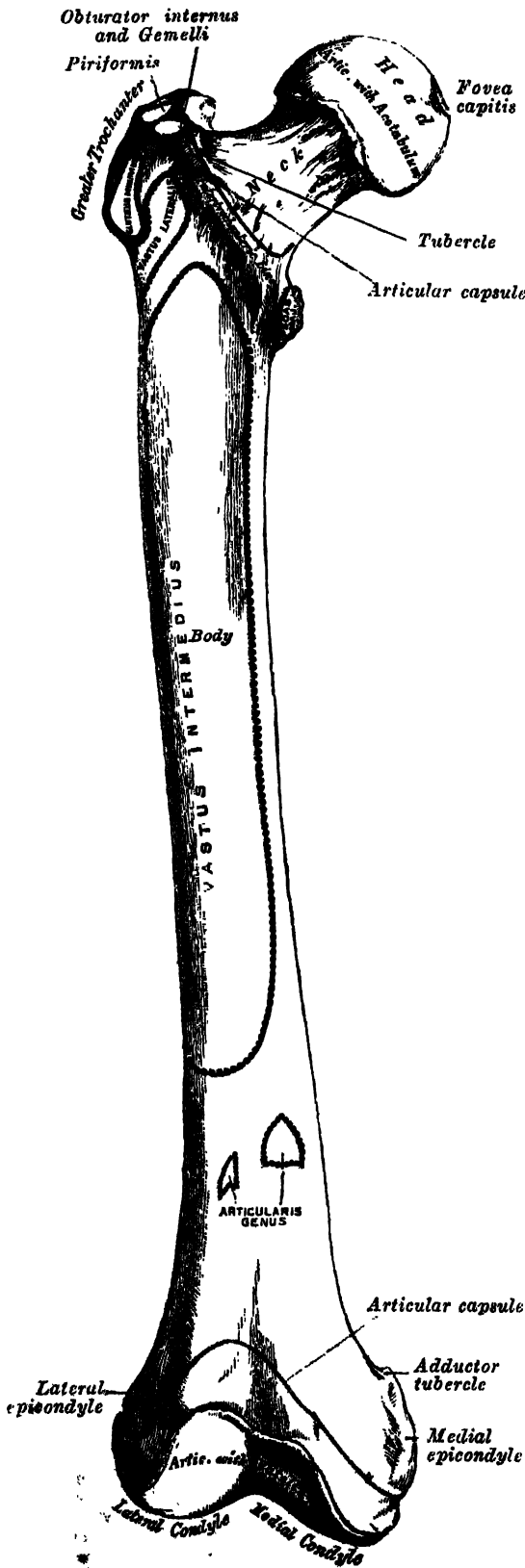
The femur (figs. 407 and 408), the longest and strongest bone in the skeleton, is cylindrical in the greater part of its extent. In the erect posture it is placed

FIG. 406.—Upper extremity of right femur, viewed from behind and above.



obliquely, being separated above from its fellow by an interval which corresponds to the breadth of the pelvis, but inclining gradually downwards and medialwards, so as to approach its fellow below, for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies in different persons, and is greater in the female than in

FIG. 407.—Right femur. Anterior surface.



the male, on account of the greater breadth of the pelvis. The femur has a body and two extremities.

The upper extremity (fig. 406) comprises a head, a neck, and a greater and lesser trochanter.

The head is globular and forms rather more than a hemisphere; it articulates with the acetabulum of the hip-bone, and is directed upwards, medialwards, and a little forwards. Its surface is smooth, except at an ovoid depression, the *fovea capitis femoris*, which is situated a little below and behind the centre of the head, and gives attachment to the ligamentum teres of the hip-joint.

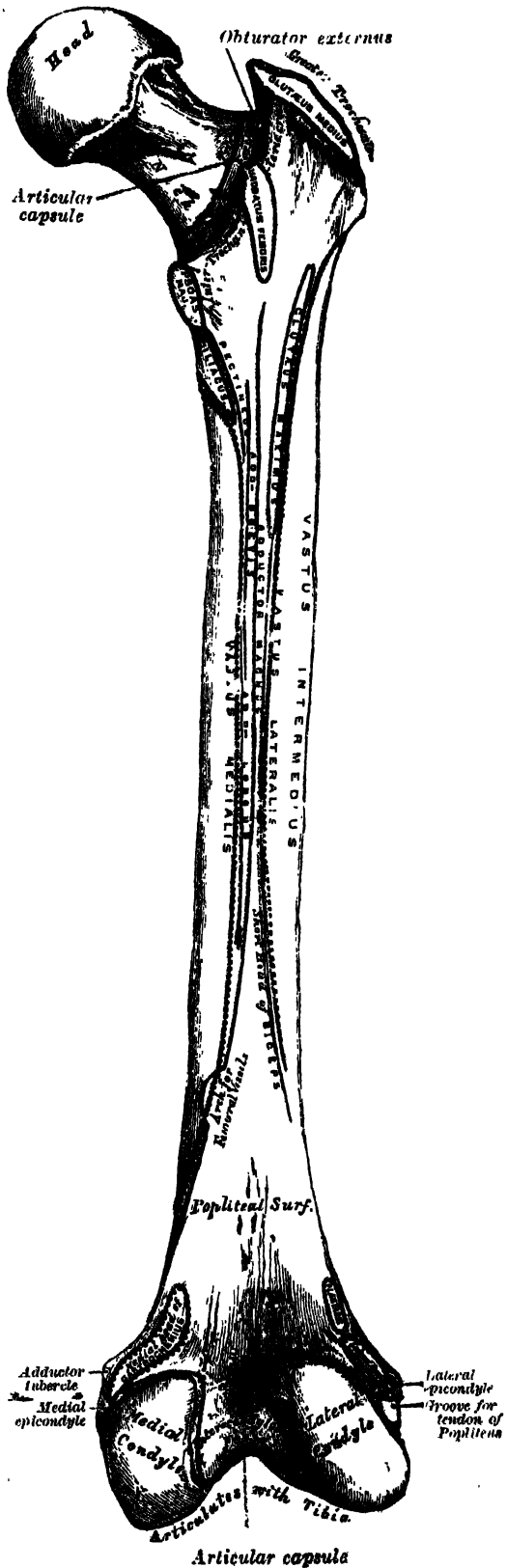
The neck is flattened anteroposteriorly; it connects the head with the body, and forms with the latter an angle of about 125° . The angle decreases during the period of growth, but after full growth has been attained it does not usually undergo any change; in the female, in consequence of the increased width of the pelvis, it is less than in the male. In addition to projecting upwards and medialwards from the body of the femur, the neck projects somewhat forwards; the amount of this forward projection is extremely variable, but on an average is from 12° to 14° .

The neck is contracted in the middle, and broader laterally than medially. The vertical diameter of the lateral half is increased by the obliquity of the lower edge, which slopes downwards to join the body at the level of the lesser trochanter; the medial half is smaller, and of a more circular shape. The anterior surface of the neck is perforated by numerous vascular foramina. Along the upper part, and encroaching on the line of junction of this surface with the head is a shallow, rough groove, best marked in elderly subjects; this groove lodges the orbicular fibres of the capsule of the hip-joint.

The *posterior surface* is more concave than the anterior, and usually exhibits a shallow, oblique groove for the tendon of the *Obturator externus*; the posterior part of the capsule of the hip-joint is attached to the neck about 1 cm. above the intertrochanteric crest. The *superior border*, short and thick, ends laterally at the greater trochanter, and is perforated by large foramina. The *inferior border*, long and narrow, curves a little backwards, and ends at the lesser trochanter.

The *greater trochanter* is a large, irregular, quadrilateral eminence, at the junction of the neck and the upper part of the body. It is directed upwards, lateralwards, and a little backwards, and, in the adult, its superior border is on a level with the centre of the head. It has two surfaces and four borders. The *lateral surface*, quadrilateral in form, is broad, rough, convex, and marked by a diagonal impression, which extends from the posterosuperior to the anteroinferior angle, and serves for the insertion of the tendon of the *Glutæus medius*. Above the impression is a triangular surface, sometimes rough for part of the tendon of the same muscle, sometimes smooth for the interposition of a bursa between the tendon and the bone. Below and behind the diagonal impression is a smooth, triangular surface, over which the tendon of the *Glutæus maximus* plays, a bursa being interposed. The *medial surface* is of much less extent than the lateral; at its base is a deep depression, the *trochanteric fossa*, for the insertion of the tendon of the *Obturator externus*, and above and slightly in front of this an impression for the insertion of the *Obturator internus* and *Gemelli*. The *superior border* is free; it is thick and irregular, and near its centre is an impression for the insertion of the *Piriformis*. The *inferior border* corresponds to the line of junction of the base

FIG. 408.—Right femur. Posterior surface.



of the trochanter with the lateral surface of the body; it is marked by a rough, prominent, slightly curved ridge, which gives origin to the upper part of the *Vastus lateralis*. The *anterior border* is prominent and somewhat irregular; it affords insertion at its lateral part to the *Glutæus minimus*. The *posterior border* is a prominent rounded edge, which bounds the back of the trochanteric fossa, and forms the upper part of the intertrochanteric crest.

The *lesser trochanter* is a conical eminence which projects from the lower and posterior part of the base of the neck. From it three borders extend; two of these are directed upwards—a *medial* continuous with the lower border of the neck; a *lateral* with the intertrochanteric crest; the third or *inferior* is continuous with the middle division of the *linea aspera*. The *summit* of the trochanter is rough, and gives insertion to the tendon of the *Psoas major*.

A prominence, of variable size, occurs at the junction of the upper part of the front of the neck with the greater trochanter, and is called the *tubercle* of the femur. Running downwards and medialwards from it is the *intertrochanteric line*; it winds round the medial side of the body of the bone, in front of and below the lesser trochanter, and ends about 5 cm. below this eminence in the *linea aspera*. Its upper half is rough, and affords attachment to the iliofemoral ligament of the hip-joint; its lower half is less prominent, and gives origin to the upper part of the *Vastus medialis*. On the posterior surface a prominent ridge, the *intertrochanteric crest*, runs obliquely downwards and medialwards from the summit of the greater trochanter to the lesser trochanter; its upper half forms the posterior border of the greater trochanter. A slight ridge, the *linea quadrata*, is sometimes seen commencing about the middle of this crest, and reaching vertically downwards for about 5 cm. along the back part of the body; it gives attachment to the *Quadratus femoris* and a few fibres of the *Adductor magnus*; as a rule, there is merely a slight thickening about the middle of the intertrochanteric crest, marking the attachment of the upper part of the *Quadratus femoris*.

The *body* or *shaft*, almost cylindrical in form, is a little broader above than in the centre, broadest and somewhat flattened from before backwards below. It is slightly arched, so as to be concave behind, where it is strengthened by a prominent longitudinal crest, the *linea aspera*. It has three borders and three surfaces. Of the borders, one, the *linea aspera*, is posterior, one is medial, and the other, lateral.

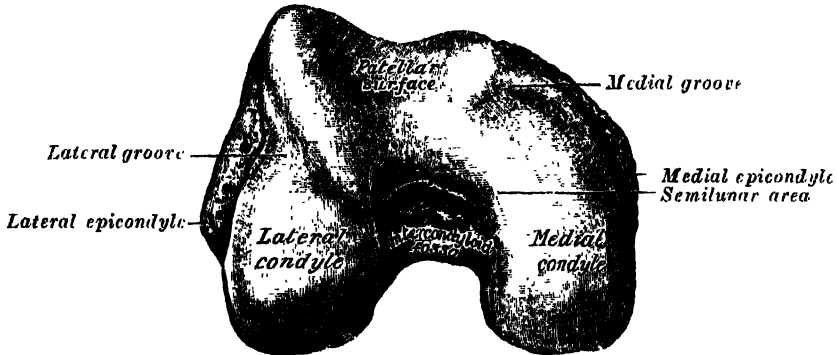
The *linea aspera* (fig. 408) is a longitudinal crest, on the middle third of the bone; it has a medial and a lateral lip, and a narrow, rough, intermediate line. Three ridges, lateral, intermediate and medial, run upwards from the *linea aspera*. The lateral ridge is very rough, and ascends to the base of the greater trochanter; it is termed the *gluteal tuberosity*, and gives insertion to part of the *Glutæus maximus*; its upper part is often elongated into a roughened crest, on which a rounded tubercle, the *third trochanter*, is occasionally developed. The intermediate ridge or *pectineal line* is continued to the base of the lesser trochanter and gives insertion to the *Pectineus*. The medial ridge is lost in the intertrochanteric line. The lips of the *linea aspera* diverge below and are prolonged as two epicondylar ridges, enclosing between them a triangular area, the *popliteal surface*, which forms the upper part of the floor of the popliteal fossa. The lateral epicondylar ridge is the more prominent, and descends to the summit of the lateral condyle. The medial ridge is less marked, especially at its upper part, where it is crossed by the femoral artery; it ends below, at the summit of the medial condyle, in the *adductor tubercle*, which affords insertion to the tendon of the *Adductor magnus*. In about 80 per cent. of specimens a rounded tubercle is present on the lower part of the popliteal surface, just above the medial condyle; to it the upper part of the medial head of the *Gastrocnemius* is attached.*

From the medial lip of the *linea aspera* and its prolongations above and below, the *Vastus medialis* arises; and from the lateral lip and its upward prolongation, the *Vastus lateralis* takes origin. The *Adductor magnus* is inserted into the *linea aspera*, and to its lateral prolongation above, and its medial prolongation below. Between the *Vastus lateralis* and the *Adductor magnus* the *Glutæus maximus* is attached above, and the short head of the

* F. G. Parsons, *Journal of Anatomy and Physiology*, vol. xlviii. p. 267, and J. S. B. Stopford, *Journal of Anatomy and Physiology*, vol. xlix. p. 80.

Biceps femoris below. Between the Adductor magnus and the Vastus medialis four muscles are inserted: the Iliacus and Pectineus above; the Adductor brevis and Adductor longus below. A little below the middle of the linea aspera is the orifice of the nutrient canal, which is directed obliquely upwards.

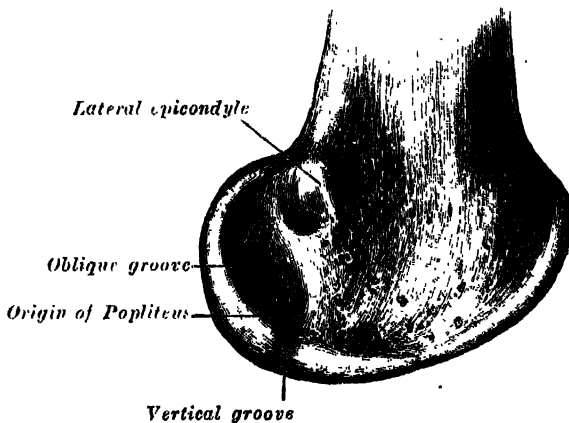
FIG. 409.—Lower extremity of right femur, viewed from below.



The *lateral* and *medial borders* of the femur are only slightly marked: the lateral extends from the anteroinferior angle of the greater trochanter to the front of the lateral condyle: the medial from the intertrochanteric line, at the level of the lesser trochanter, to the front of the medial condyle.

The *anterior surface* of the body is between the lateral and medial borders: it is smooth, convex, broader above and below than in the centre. The Vastus intermedius arises from its upper three-fourths, and from the upper part of its lower fourth the Articularis genus takes origin. The *lateral surface* is between the lateral border and the linea aspera: it is continuous above with the lateral surface of the greater trochanter, below with that of the lateral condyle: the

FIG. 410.—Lateral surface of lower end of right femur.

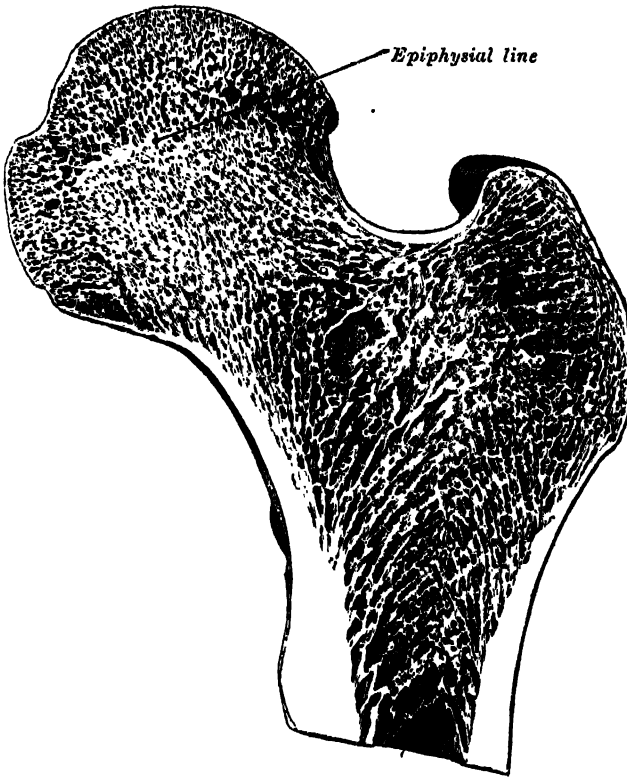


Vastus intermedius arises from its upper three-fourths. The *medial surface* is between the medial border and the linea aspera: it is continuous above with the lower border of the neck, below with the medial side of the medial condyle: it is covered by the Vastus medialis.

The **lower extremity** (fig. 409), larger than the upper, consists of two oblong eminences known as the *condyles*; in front, these are but slightly prominent, and are separated by a smooth shallow articular depression called

the *patellar surface*; behind, they project considerably, and are separated by a deep notch, the *intercondyloid fossa*. The *lateral condyle* is the more prominent anteriorly, and is the broader both in its anteroposterior and transverse diameters. The *medial condyle* projects to a lower level than the lateral, when the femur is held with its body perpendicular; when, however, the bone is in its natural oblique position the lower surfaces of the two condyles lie in the same horizontal plane. The condyles are not quite parallel with one another; the long axis of the lateral is almost directly anteroposterior, but that of the medial runs backwards and medialwards. Their opposed surfaces are small, rough, and concave, and form the walls of the intercondyloid fossa; this fossa is limited above by a ridge, the *intercondyloid line*, and below by the central

FIG. 411.—Longitudinal section of head and neck of femur.



part of the posterior margin of the patellar surface. The *posterior cruciate ligament* of the knee-joint is attached to the lower and front part of the medial wall of the fossa, and the *anterior cruciate ligament* to the upper and posterior part of its lateral wall. Each condyle is surmounted by an elevation, the *epicondyle*. The *medial epicondyle* is a large convex eminence to which the *tibial collateral ligament* of the knee-joint is attached. At its upper part is the *adductor tubercle*, already referred to, and behind it is a rough impression which gives origin to the medial head of the *Gastrocnemius*. The *lateral epicondyle* (fig. 410), smaller and less prominent than the medial, gives attachment to the *fibular collateral ligament* of the knee-joint. Directly below it is a small depression from which a deep, oblique groove curves upwards and backwards to the posterior extremity of the condyle. This groove is separated from the articular surface of the condyle by a rounded lip, across the anterior part of which a vertical shallow groove descends from the depression. In the recent state these grooves are covered with cartilage. The *Popliteus* arises from the depression below the epicondyle; its tendon lies in the oblique groove when the knee is flexed and in the vertical groove when the knee is extended.

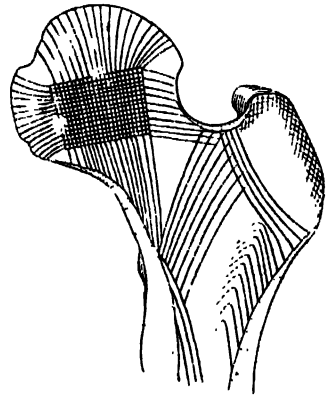
Above and behind the lateral epicondyle is an area for the origin of the lateral head of the *Gastrocnemius*, above and medial to which the *Plantaris* arises.

The *articular surface* of the lower end of the femur occupies the anterior, inferior, and posterior surfaces of the condyles. Its front part is named the *patellar surface* and articulates with the patella; it presents a median groove between two convexities, the lateral of which is broader, more prominent, and ascends farther than the medial. The lower and posterior parts of the articular surface constitute the *tibial surfaces* for articulation with the corresponding condyles of the tibia and the menisci of the knee-joint. These surfaces are separated from one another by the intercondyloid fossa and from the patellar surface by faint grooves which extend obliquely across the condyles. The lateral groove is the better marked; it runs lateralwards and slightly forwards from the front part of the intercondyloid fossa, and expands to form a triangular depression which rests upon the anterior portion of the lateral meniscus when the knee-joint is fully extended. The medial groove is less distinct than the lateral, and exists only on the medial part of the condyle; it receives the anterior edge of the medial meniscus when the knee-joint is extended. Where the groove ceases laterally the patellar surface is seen to be continued backwards as a semilunar area close to the anterior part of the intercondyloid fossa; this semilunar area articulates with the medial vertical facet of the patella in forced flexion of the knee-joint. The tibial surfaces of the condyles are convex from side to side and from before backwards. Each presents a double curve, its posterior segment being an arc of a circle, its anterior part of a cycloid.*

Structure.—The body of the femur is a cylinder of compact bone, hollowed by a large medullary canal. The wall of the cylinder is thick and dense in the middle third of the body, where the bone is narrowest and the medullary canal best formed; but above and below this the wall becomes thinner, while the medullary canal is gradually filled up by spongy substance, so that the upper (fig. 411) and lower ends of the body, and the articular extremities more especially, consist of spongy substance, invested by a thin compact layer.

The cancelli in the ends of the femur are disposed along the lines of greatest pressure and tension. In the upper end (fig. 412) the chief lamellæ are arranged in the following manner. A series of bony planes at right angles to the articular surface of the head converge to a central dense wedge; this wedge is supported by strong lamellæ which extend to the sides of the neck and are specially marked along its upper and lower borders. Any force therefore applied to the head of the femur is transmitted directly to the central wedge and thence to the junction of the neck with the body. This junction is specially strengthened by a series of dense lamellæ which extend from the lesser trochanter to the lateral end of the superior border of the neck; this arrangement will obviously oppose considerable resistance to either tensile or shearing force. A smaller bar stretching across the junction of the greater trochanter with the neck and body resists the shearing force of the muscles attached to this prominence. These two bars, one at the junction of body and neck, the other at the junction of body and greater trochanter, form the upper layers of a series of arches which extend across between the sides of the body and transmit to the body forces applied to the upper end of the bone. In the spongy substance of the neck is a thin vertical plate of bone, the *calcar femorale*, which springs from the compact wall of the body in the region of the *linea aspera*. Medially it is attached to the inner surface of the posterior wall of the neck of the bone; laterally it continues the plane of the posterior wall of the neck into the greater trochanter, where it shades off into the general spongy

FIG. 412.—Scheme showing disposition of principal cancellous lamellæ in upper extremity of femur.



* A *cycloid* is a curve traced by a point in the circumference of a wheel when the wheel is rolled along in a straight line.

substance. It is thus situated in a plane anterior to the intertrochanteric crest and to the base of the lesser trochanter (fig. 413).

In the lower end, the cancelli spring on all sides from the inner surface of the cylinder, and descend in a perpendicular direction to the articular surface, the cancelli being strongest and having a more accurately perpendicular course above the condyles. In addition to this, there are horizontal planes of cancellous tissue, so that the spongy substance in this situation presents an appearance of being mapped out into a series of cubical spaces.

Ossification (figs. 414, 415, 416).—The femur is ossified from five centres: one each for the body, head, greater trochanter, lesser trochanter, and lower extremity.

FIG. 413.—Oblique section of upper extremity of femur showing calcar femorale.

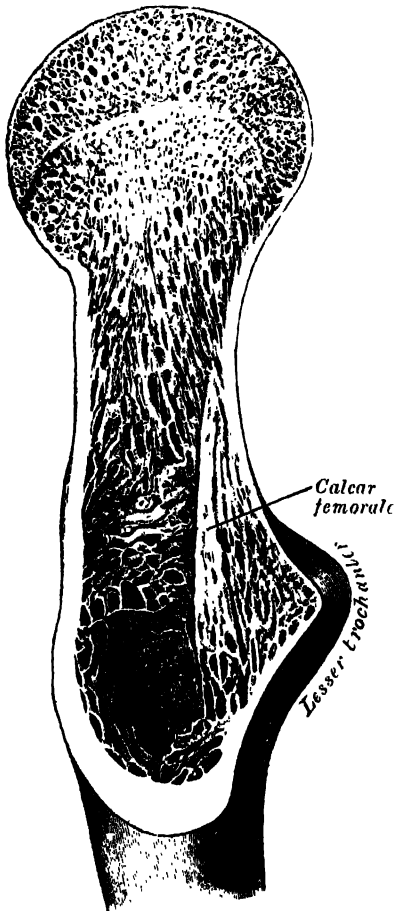
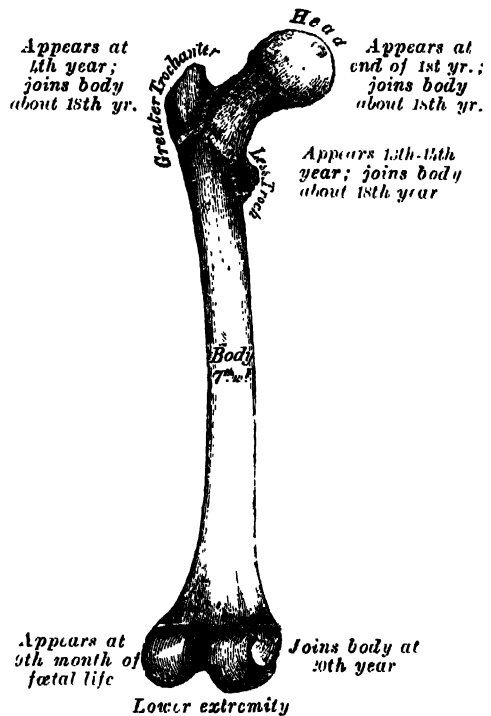


FIG. 414.—Plan of ossification of the femur. From five centres.

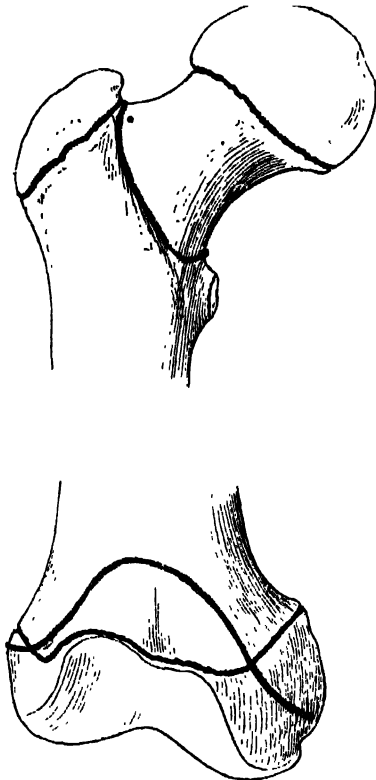


Except the clavicle, it is the first of the long bones to show traces of ossification; the latter begins in the middle of the body in the seventh week of foetal life, and extends upwards and downwards. The secondary centres appear as follows: in the lower extremity, during the ninth month of foetal life (from this centre the condyles and epicondyles are formed); in the head at the end of the first year after birth; in the greater trochanter during the fourth year; and in the lesser trochanter between the thirteenth and fourteenth years. The epiphyses, derived from the secondary centres, fuse independently with the body after puberty; the lesser trochanter joins first, then the greater, then the head, and, lastly, the inferior extremity which is not united until the twentieth year.

Applied Anatomy.—The lower end of the femur is the only epiphysis in which ossification has commenced at the time of birth. The presence of this ossific centre is, therefore,

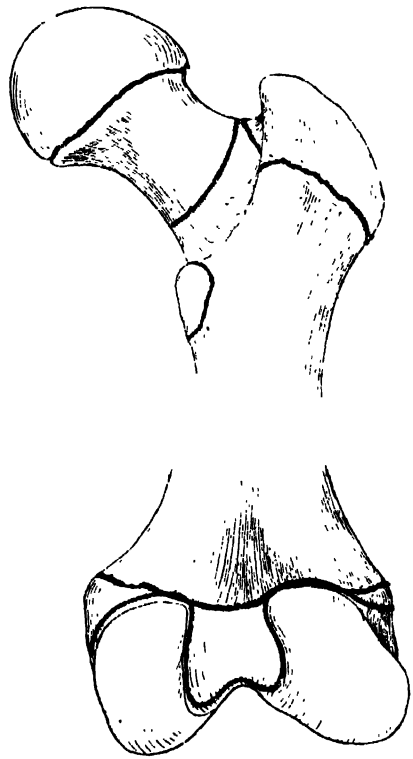
a proof, in a newly-born child found dead, that the child has arrived at the full period of uterogestation, and is always relied upon in medico-legal investigations. The position of the epiphysial plate should be carefully noted. It is on a level with the adductor tubercle, and the epiphysis does not, therefore, form the whole of the synovial covered portion of the lower end of the bone. It is essential to bear this point in mind in performing excision of the knee, since growth in length of the femur takes place chiefly from the lower epiphysis, and any interference with the epiphysial cartilage in a young child would involve such ultimate shortening of the limb, from want of growth, as to render the limb almost useless. Separation of the lower epiphysis may take place up to the age of twenty, at which time it becomes completely joined to the body of the bone; but, as a matter of fact, few cases occur after the age of sixteen or seventeen. The epiphysis of the head of the femur is the seat of origin, in a large number of cases, of tuberculous disease of the hip-joint. In the majority of cases the disease begins in the highly vascular and growing

FIG. 415.—Epiphysial lines of femur in a young adult. Anterior aspect.



The lines of attachment of the articular capsules are in blue.

FIG. 416.—Epiphysial lines of femur in a young adult. Posterior aspect.



The lines of attachment of the articular capsules are in blue.

tissue at the end of the body in the neighbourhood of the epiphysial cartilage, and extends into the joint. The epiphysis for the head is entirely intracapsular.

Fractures of the femur are divided, like those of the other long bones, into fractures of the upper end; of the body; and of the lower end. The fractures of the upper end may be classified into (1) fracture of the neck; (2) fracture at the junction of the neck with the greater trochanter; (3) fracture of the greater trochanter; and (4) separation of the epiphysis, either of the head or of the greater trochanter. The first of these, fracture of the neck, is usually termed *intracapsular* fracture, but this is scarcely a correct designation, as, owing to the attachment of the articular capsule, the fracture is partly within and partly without the capsule when the fracture occurs at the lower part of the neck. It generally takes place in old people, principally women, and usually from a very slight degree of indirect violence. Probably the main cause of its occurrence in old people is the senile degenerative change which takes place in the bone. Merkel believes that it is mainly due to the absorption of the *calcar femorale*. As a rule the fragments become united by fibrous tissue, but frequently no union takes place, and the opposed surfaces become smooth and eburnated.

Fractures at the junction of the neck with the greater trochanter are usually termed *extracapsular*, but this designation is also incorrect, as the fracture is partly within the capsule, which is attached in front to the intertrochanteric line below the line of fracture. These fractures are produced by direct violence to the greater trochanter, as from a fall laterally on the hip. From the manner in which the accident is caused the neck of the bone is driven into the trochanter, where it may remain impacted or the trochanter may be split into two or more fragments, disimpaction resulting.

Fractures of the body may occur at any part, but the most usual situation is at or near the centre of the bone. They may be caused by direct or indirect violence. Fractures of the upper third of the body are almost always the result of indirect violence, while those of the lower third are the result, for the most part, of direct violence. Fractures of the body are generally oblique, but they may be transverse, longitudinal, or spiral. The transverse fracture occurs most frequently in children. The fractures of the lower end of the femur include transverse fracture above the condyles, the most common; and this may be complicated by a vertical fracture between the condyles, constituting the T-shaped fracture. In these cases the popliteal artery is in danger of being wounded. Oblique fracture separating either the medial or lateral condyle, and a longitudinal incomplete fracture between the condyles, may also take place.

The femur and the bones of the leg are frequently the seat of acute osteomyelitis in children. This is no doubt due to their greater exposure to injury, which is often the exciting cause of this disease. Necrosis of portions of the diaphysis frequently ensue, especially in the region of the popliteal surface of the femur, and the disease may continue for years, great trouble being experienced with discharging sinuses which periodically close and reopen to allow of the exit of pieces of dead bone.

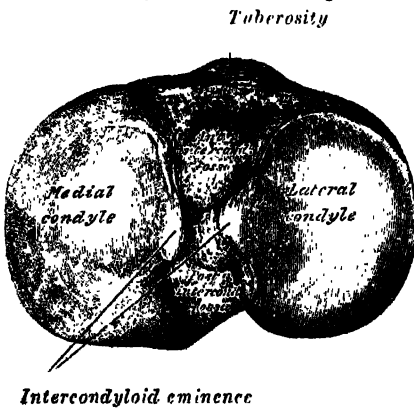
Tumours are not infrequently found growing from the femur: the most common forms being sarcoma, which may grow either from the periosteum or from the medullary tissue within the interior of the bone, and exostosis, which commonly originates in the neighbourhood of the epiphysal cartilage of the lower end. The periosteal sarcomata of the femur and most of the central growths are usually of a very high degree of malignancy, although the 'myeloid' growth, which is of but low malignancy, may also be found. The region of the lower epiphysal line is by far the commonest seat for all these tumours, and it should be noted that the lower epiphysis has the longest period of active growth, and that these tumours usually appear towards the end of the period of active growth of the bone.

Sarcomata about the upper end of the femur are seen occasionally, but very rarely in comparison with those at the lower end. Secondary carcinoma also occurs in this bone, most commonly due to a primary focus in the mamma, and spontaneous fracture of the bone may take place in these cases.

THE TIBIA

The tibia (figs. 418 and 419) is situated at the medial side of the leg, and, excepting the femur, is the longest bone of the skeleton. It is prismoid in form, expanded above, where it enters into the formation of the knee-joint, contracted in the lower third, and again enlarged, but to a lesser extent, below. It has a body and two extremities.

FIG. 417.—Upper surface of right tibia.



It enters into the formation of the knee-joint, contracted in the lower third, and again enlarged, but to a lesser extent, below. It has a body and two extremities.

The upper extremity (fig. 417) is expanded into two eminences, the *medial* and *lateral condyles*, the superior surfaces of which are smooth and articular. The medial articular surface, oval in shape, is slightly concave from side to side, and from before backwards; the lateral, nearly circular, is concave from side to side, but slightly convex from before backwards, especially at its posterior part, where it is prolonged on to

the posterior surface for a short distance. The central portions of these surfaces articulate with the condyles of the femur, while their peripheral portions support the menisci of the knee-joint, which here intervene between the two bones. Between the articular surfaces, nearer the posterior than the anterior part of the bone, is the *intercondyloid eminence* (tibial spine), surmounted on either side by a prominent tubercle, on the sides of which the

FIG. 418.—Bones of the right leg.
Anterior surface.

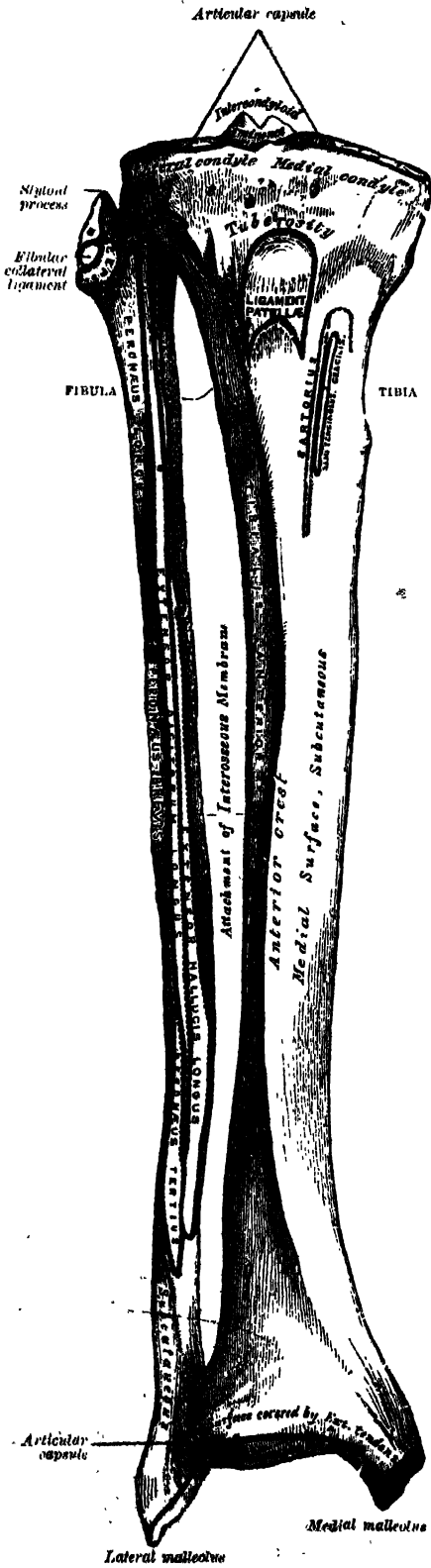
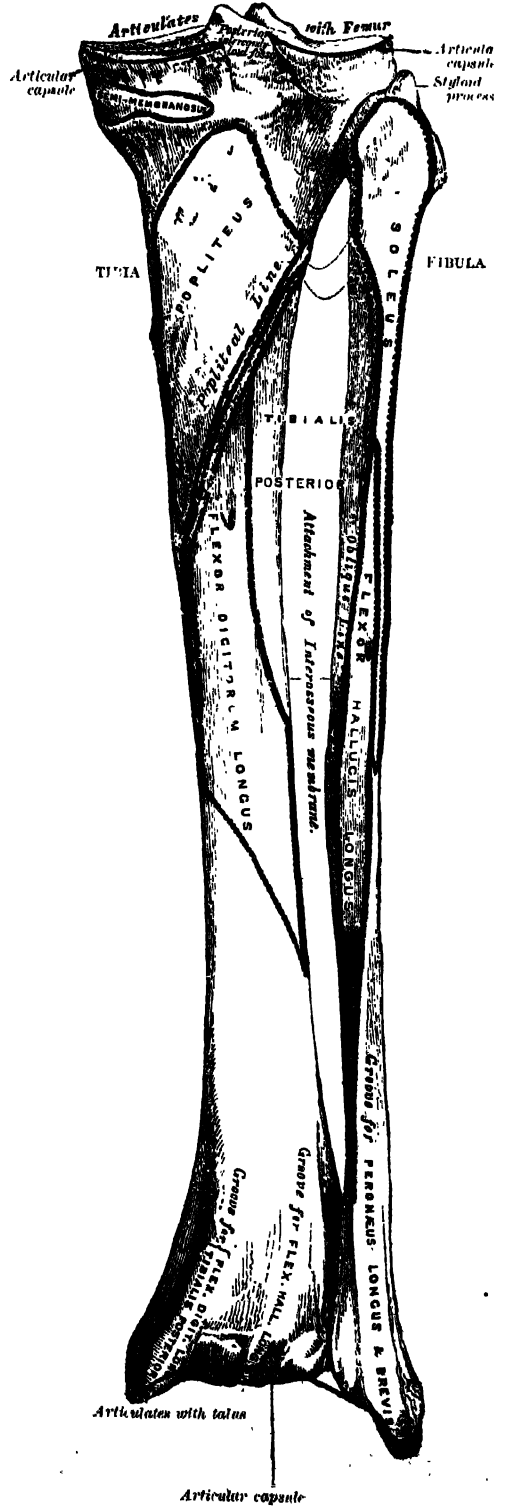


FIG. 419.—Bones of the right leg
Posterior surface.



articular surfaces are prolonged; in front of and behind the intercondyloid eminence are rough depressions, the *anterior* and *posterior intercondyloid fossæ*, for the attachment of the cruciate ligaments and the menisci of the knee-joint. The anterior surfaces of the condyles are continuous with one another, forming a large, triangular, somewhat flattened area; this area is perforated by vascular foramina, and ends below in an oblong elevation, the *tuberosity* of the tibia, which gives attachment to the *ligamentum patellæ*; a *bursa* intervenes between the deep surface of the ligament and the part of the bone immediately above the tuberosity. The *medial condyle* is grooved posteriorly, for the insertion of the tendon of the *Semimembranosus*; its medial surface, convex, rough and prominent, gives attachment to the posterior part of the *tibial collateral ligament*. The *lateral condyle* presents posteriorly a flat, nearly circular, articular facet, directed downwards, backwards, and lateralwards, for articulation with the head of the fibula. Its lateral surface is convex, rough and prominent in front: on it is an eminence, situated on a level with the upper border of the tuberosity and at the junction of its anterior and lateral surfaces, for the attachment of the *iliotibial tract* or *band of the fascia lata*. Just below this a slip from the tendon of the *Biceps femoris* is inserted, and a small part of the *Extensor digitorum longus* takes origin.

The *body or shaft* has three crests or margins and three surfaces.

The *anterior crest* or *shin*, the most prominent, begins above at the tuberosity, and ends below at the anterior margin of the medial malleolus. It is sinuous and prominent in its upper two-thirds, but smooth and rounded below; it gives attachment to the deep fascia of the leg.

The *medial margin* is smooth and rounded above and below, but more prominent in the centre; it begins at the posterior part of the medial condyle, and ends at the posterior border of the medial malleolus; its upper part gives attachment to the *tibial collateral ligament* of the knee-joint to the extent of about 5 cm., and insertion to some fibres of the *Popliteus*; from its middle third some fibres of the *Soleus* and *Flexor digitorum longus* take origin.

The *interosseous crest* gives attachment to the *crural interosseous membrane* (fig. 422) and is most distinct in the middle third of the bone; it begins above in front of the fibular articular facet, and bifurcates below to form the boundaries of a triangular rough surface, the *fibular notch*, for the attachment of the *interosseous ligament* connecting the tibia and fibula.

The *medial surface* is smooth, convex, and broader above than below; its upper third is covered by the aponeurosis derived from the tendon of the *Sartorius*, and by the tendons of the *Gracilis* and *Semitendinosus* which are inserted into this part of the bone; the rest of the surface is subcutaneous.

The *lateral surface* is narrower than the medial; on its upper two-thirds is a shallow groove for the origin of the *Tibialis anterior*; its lower third is smooth, convex, curves gradually forwards to the anterior aspect of the bone, and is covered by the tendons of the *Tibialis anterior*, *Extensor hallucis longus*, and *Extensor digitorum longus*, arranged in this order from the medial side.

At the upper part of the *posterior surface* (fig. 419) is a prominent ridge, the *popliteal line*, which descends obliquely from the fibular articular facet to the medial border, near the junction of its upper and middle thirds; the fascia covering the *Popliteus* muscle is attached to it, and parts of the *Soleus*, *Flexor digitorum longus*, and *Tibialis posterior* take origin from it. Above the line is a triangular area, into the greater part of which the *Popliteus* is inserted; immediately below the line is the *nutrient foramen*, which is large and directed obliquely downwards. The middle third of the posterior surface is divided into two areas by a vertical ridge which begins at the popliteal line and is usually well marked above, but indistinct below; the medial and broader area gives origin to the *Flexor digitorum longus*, the lateral and narrower to part of the *Tibialis posterior*. The lower part of the posterior surface is smooth and covered by the *Tibialis posterior*, *Flexor digitorum longus*, and *Flexor hallucis longus*.

The *lower extremity* is prolonged downwards on its medial side as a strong process, the *medial malleolus*. The *inferior articular surface* is quadrilateral, and articulates with the talus. It is broader in front than behind, concave from before backwards, and near the middle is traversed in this direction by a slight elevation. It is continuous with the articular surface on the lateral

side of the medial malleolus. The *anterior surface* is smooth and rounded above, and covered by the tendons of the Extensor muscles; at its lower margin is a furrow for the attachment of the articular capsule of the ankle-joint. The lateral part of the *posterior surface* is traversed by a shallow groove, directed obliquely downwards and medialwards, in which the tendon of the Flexor hallucis longus lies. On the *lateral surface* is a triangular rough depression, the *fibular notch*, for the attachment of the interosseous ligament connecting the tibia with the fibula; in the recent state, the lower border of this notch is occasionally covered with cartilage, and articulates with the fibula. The notch is bounded by two prominent borders, continuous above with the interosseous crest; their lower parts afford attachment to the anterior and posterior ligaments of the lateral malleolus.

The *medial malleolus* is a strong pyramidal process, flattened from side to side. Its medial surface is convex and subcutaneous; its *lateral* or articular

FIG. 420.—Plan of ossification of the tibia.
From three centres.

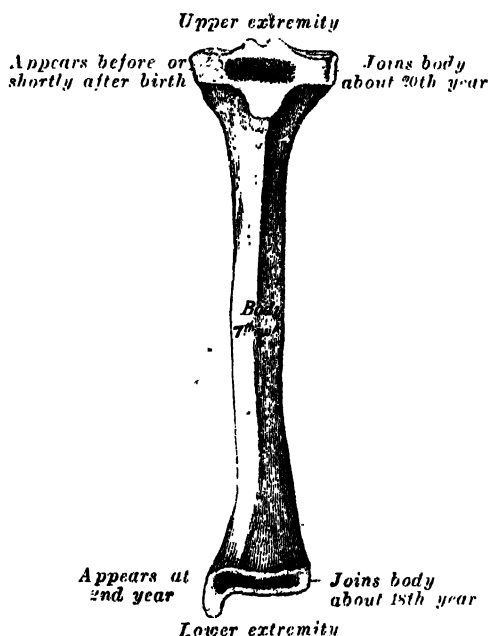
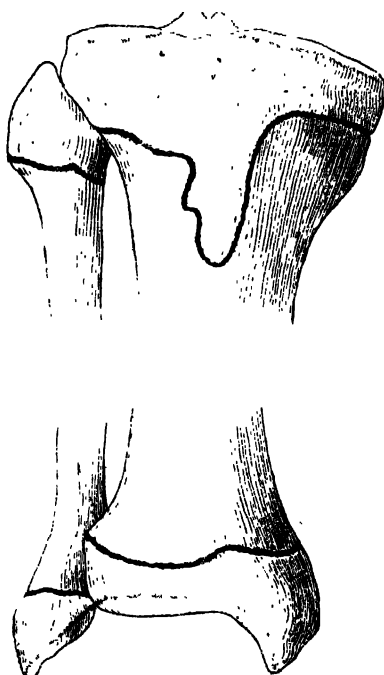


FIG. 421.—Epiphysial lines of tibia and fibula in a young adult.
Anterior aspect.



The lines of attachment of the articular capsules are in blue.

surface, smooth and slightly concave, articulates with the talus; its anterior border is rough, for the attachment of the anterior fibres of the deltoid ligament of the ankle-joint; on its *posterior border* is a broad groove, the *malleolar sulcus*, directed obliquely downwards and medialwards, and occasionally double; it lodges the tendons of the Tibialis posterior and Flexor digitorum longus. The *summit* of the malleolus is marked behind by a depression, for the attachment of the deltoid ligament.

Structure. The structure of the tibia is like that of the other long bones. The compact wall of the body is thickest at the junction of the middle with the lower one-third of the bone.

Ossification.—The tibia is ossified from three centres (figs. 420, 421): one for the body and one for either end. Ossification begins in the centre of the body about the seventh week of foetal life. The centre for the upper end appears before or shortly after birth, and from it a thin tongue-shaped process extends downwards

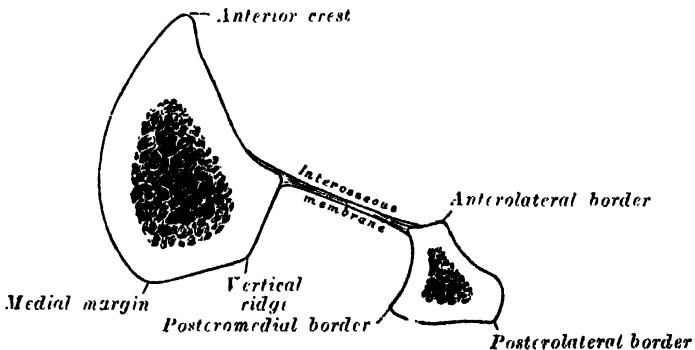
in front, to form the tuberosity (fig. 421); the centre for the lower end appears in the second year. The lower end joins the body at about the eighteenth year; the upper about the twentieth year. Two additional centres occasionally exist, one for the tongue-shaped process of the upper end, which forms the tuberosity, and one for the medial malleolus.

THE FIBULA

The **fibula** (figs. 418 and 419) is placed on the lateral side of the tibia, with which it is connected above and below. In proportion to its length it is the most slender of all the long bones. Its upper extremity articulates with the back of the lateral condyle of the tibia, below the level of the knee-joint. The bone inclines a little forwards so that its lower extremity or lateral malleolus is on a plane anterior to that of the upper end; it projects below the tibia, and forms the lateral part of the ankle-joint.

The **upper extremity** or **head** is of an irregular quadrate form, and has a flattened articular surface, directed upwards, forwards, and medialwards, for articulation with the lateral condyle of the tibia. On its lateral side is a thick and rough prominence, continued behind into a pointed eminence, the *apex* or *styloid process*, which projects upwards from the posterior part of the head.

FIG. 422.—Transverse section of tibia and fibula, showing attachment of interosseous membrane.



The prominence, at its upper and lateral part, gives attachment to the tendon of the *Biceps femoris* and to the *fibular collateral ligament* of the knee-joint, the ligament dividing the tendon into two parts. The remaining part of the head is rough, for the attachment of muscles and ligaments; in front is a tubercle for the origin of the upper fibres of the *Peroneus longus*, and a surface for the attachment of the *anterior ligament* of the head of the bone; behind, another tubercle, for the attachment of the *posterior ligament* of the head and a few fibres of the *Soleus*.

The **body** or **shaft** has four borders—*anterolateral*, *anteromedial*, *posterolateral*, and *posteromedial*; and four surfaces—*anterior*, *posterior*, *medial*, and *lateral*.

The *anterolateral border* begins above in front of the head, runs vertically downwards to a little below the middle of the bone, and then curving lateralwards, bifurcates to embrace a triangular subcutaneous surface immediately above the lateral malleolus. This border gives attachment to the *anterior fibular intermuscular septum* which separates the *Extensor muscles* on the anterior surface of the leg from the *Peroneus longus* and *Peroneus brevis* on the lateral surface.

The *anteromedial border*, or *interosseous crest*, is close to the medial side of the *anterolateral border*, and runs nearly parallel with it in the upper third of its extent, but diverges from it in the lower two-thirds. It begins above just below the head of the bone, and is sometimes quite indistinct for about 2.5 cm.; it ends at the apex of a rough triangular surface which is situated

above the articular facet of the lateral malleolus. It serves for the attachment of the crural interosseous membrane (fig. 422) which separates the extensor muscles in front from the flexor muscles behind.

The posterolateral border is prominent; it begins above at the styloid process of the head and ends below in the posterior border of the lateral malleolus. It is directed lateralwards above, backwards in the middle of its course, backwards and a little medialwards below, and gives attachment to the posterior fibular intermuscular septum which separates the Peronæi on the lateral surface from the Flexor muscles on the posterior surface.

The posteromedial border, sometimes called the oblique line, begins above at the medial side of the head and ends by joining the interosseous crest at the lower fourth of the bone; it is well marked and prominent at the

FIG. 423.—Lower extremity of right fibula.
Medial aspect.

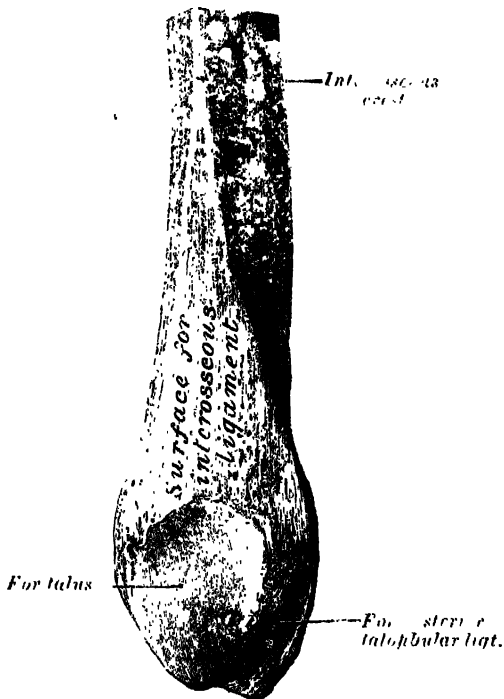
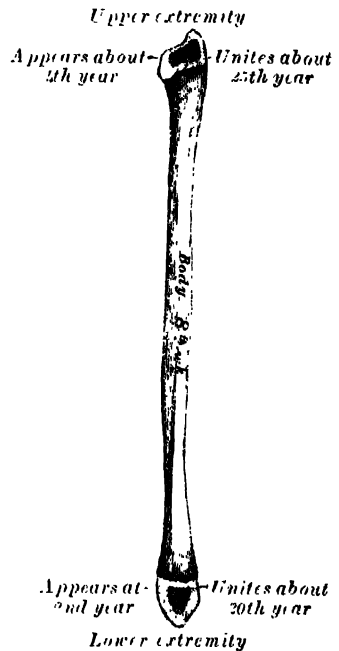


FIG. 424.—Plan of ossification of the fibula. From three centres.



upper and middle parts of the bone. It gives attachment to an aponeurosis which separates the Tibialis posterior from the Soleus and Flexor hallucis longus.

The anterior surface is the interval between the anterolateral and anteromedial borders. It is narrow and flat in the upper third of its extent; broader and grooved longitudinally in its lower third; it serves for the origin of the Extensor digitorum longus, Extensor hallucis longus, and Peroneus tertius.

The posterior surface is between the posterolateral and posteromedial borders; it is continuous below with the triangular area above the articular surface of the lateral malleolus, and is directed backwards above and medialwards below. Its upper third is rough for the origin of the Soleus; its lower part, triangular in shape, is connected to the tibia by a strong interosseous ligament; the intervening part is covered by the fibres of origin of the Flexor hallucis longus. Near the middle of this surface is the nutrient foramen, which is directed downwards.

The medial surface, between the anteromedial and posteromedial borders, is concave and gives origin to part of the Tibialis posterior.

The lateral surface is between the anterolateral and posterolateral borders.

Broad and often deeply grooved, it is directed lateralwards in its upper two-thirds, and backwards in its lower third, where it is continuous with the posterior border of the lateral malleolus. This surface gives origin to the *Peronæi longus* and *brevis*, and its lower part is covered by the tendons of these muscles.

The lower extremity, or lateral malleolus, is of a pyramidal form, and somewhat flattened from side to side; it descends to a lower level than the medial malleolus. The lateral surface is convex, and continuous with the triangular, subcutaneous surface on the lateral side of the body. The medial surface (fig. 423) presents in front a smooth triangular surface, convex from above downwards, which articulates with the lateral side of the talus. Behind and beneath the articular surface is a rough depression for the attachment of the posterior talofibular ligament. The anterior border is thick and rough, and marked below by a depression for the attachment of the anterior talofibular ligament. The posterior border is broad, and presents a shallow groove which is traversed by the tendons of the *Peronæi longus* and *brevis*. The summit is rounded, and gives attachment to the calcaneo-fibular ligament.

Ossification.—The fibula is ossified from three centres (fig. 424): one for the body, and one for either end. Ossification begins in the body about the eighth week of foetal life, in the lower end during the second year, and in the upper about the fourth year. The lower epiphysis, the first to ossify, unites with the body about the twentieth year; the upper about the twenty-fifth year.

Applied Anatomy.—In fractures of the bones of the leg, both bones are generally involved, but either bone may be broken separately, the fibula more frequently than the tibia. Fracture of both bones may be caused by either direct or indirect violence. When it occurs from indirect force, the fracture in the tibia is at the junction of the middle with the lower one-third of the bone. Many causes conduce to render this the weakest part of the bone. The fracture of the fibula is usually at a rather higher level. These fractures present great variety, both as regards their direction and condition. They may be oblique, transverse, longitudinal, or spiral. When oblique, they are for the most part the result of indirect violence, and the direction of the fracture is downwards, forwards, and medialwards in many cases, but may be downwards and lateralwards, or downwards and backwards. When transverse, the fracture is often at the upper part of the bone, and is the result of direct violence. The spiral fracture of the tibia generally starts as a vertical fissure, involving the ankle-joint, and is associated with fracture of the fibula higher up. It is the result of torsion, from twisting of the body while the foot is fixed.

Fractures of the tibia alone are almost always the result of direct violence, except where the malleolus is broken off by twists of the foot. Fractures of the fibula alone may arise from indirect or direct force, those of the lower end being usually the result of the former, and those higher up being caused by a direct blow on the part.

The tibia is the bone which is most commonly and most extensively distorted in rickets. It bends at the junction of the middle and lower third, its weakest part, and presents a curve forwards with generally some lateral displacement.

The tibia is more often the seat of acute infective necrosis than any other bone in the body, and with the formation of the sequestrum a large amount of new bony material is thrown out by the periosteum. The sequence of events in this disease can be very closely followed in the case of the tibia, and it is not uncommon to find a patient from whom the whole diaphysis of the tibia has been removed, going about with a new bone entirely of periosteal formation. Chronic bone abscess is more frequently met with in the cancellous tissue of the head or lower end of the tibia than in any other bone in the body. These abscesses are very chronic, and in most cases the result of tuberculous osteitis, although they are sometimes due to the organisms of suppuration or even the *bacillus typhosus*.

THE PATELLA

The patella (figs. 425 and 426), the largest of the sesamoid bones, is situated in front of the knee-joint in the tendon of the *Quadriceps femoris* muscle. It is flat and triangular, and has an anterior and a posterior surface, three borders, and an apex.

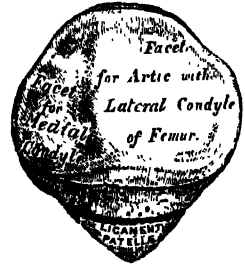
The anterior surface is convex, perforated by apertures for the passage of nutrient vessels, and marked by numerous rough, longitudinal striæ. It is separated from the integument by a bursa and is covered, in the recent state, by an expansion from the tendon of the *Quadriceps femoris*, which is continuous

below with the superficial fibres of the ligamentum patellæ. The *posterior surface* presents above a smooth, oval, articular area, divided into two facets by a vertical ridge; the ridge corresponds to the groove on the patellar surface of the femur, and the facets to the medial and lateral parts of the same surface; the lateral facet is the broader and deeper. Below the articular surface is a rough, convex, non-articular area, the lower part of which gives attachment to the ligamentum patellæ; the upper part is separated from the head of the tibia by fat.

FIG. 425.—Right patella.
Anterior surface.



FIG. 426.—Right patella.
Posterior surface.



The *base* or *superior border* is thick, and sloped from behind, downwards, and forwards: it gives attachment, except near its posterior margin, to that portion of the Quadriceps femoris which is derived from the Rectus femoris and Vastus intermedius. The *medial* and *lateral borders* are thinner and converge below: they give attachment to those portions of the Quadriceps femoris which are derived from the Vasti medialis and lateralis. Near the junction of the superior and lateral borders is a small shallow circular depression into which a part of the tendon of the Vastus lateralis is inserted.

The *apex* is pointed, and gives attachment to the ligamentum patellæ.

Structure. The patella consists of a nearly uniform dense spongy substance, covered by a thin compact lamina. The cancelli immediately beneath the anterior surface are arranged parallel with it. In the rest of the bone they radiate from the articular surface towards the other parts of the bone.

Ossification.—The patella is ossified from a single centre, which usually makes its appearance in the second or third year, but may be delayed until the sixth year. Ossification is completed about the age of puberty.

Applied Anatomy.—Fractures of the patella are of frequent occurrence. They are most often produced by muscular action—that is to say, by violent contraction of the Quadriceps femoris while the limb is in a position of semiflexion, so that the bone is snapped across the condyles of the femur and the fracture is transverse. Fracture of the patella is also produced by direct violence, such as falls on the knee, and here the fracture is usually stellate and the bone comminuted. Owing to the displacement of the fragments, and the difficulty there is in maintaining them in apposition, union takes place by fibrous tissue which may subsequently stretch, producing wide separation of the fragments and permanent lameness. Really satisfactory results after this fracture are generally only to be obtained by opening the joint and wiring the fragments together, and this is especially so when there is marked separation of the fragments owing to laceration of the retinacula.

If the fracture involve only the lower and non-articular part of the bone, it is an anatomical possibility for such to take place without injury to the synovial stratum and without involving the cavity of the knee-joint.

THE SKELETON OF THE FOOT

The skeleton of the foot (figs. 427 and 428) consists of three parts: the tarsus, metatarsus, and phalanges.

THE TARSUS

The tarsal bones (*ossa tarsi*) are seven in number: viz. the talus, calcaneus, navicular, first, second, and third cuneiforms, and the cuboid.

FIG. 427.—Bones of the right foot. Dorsal surface.

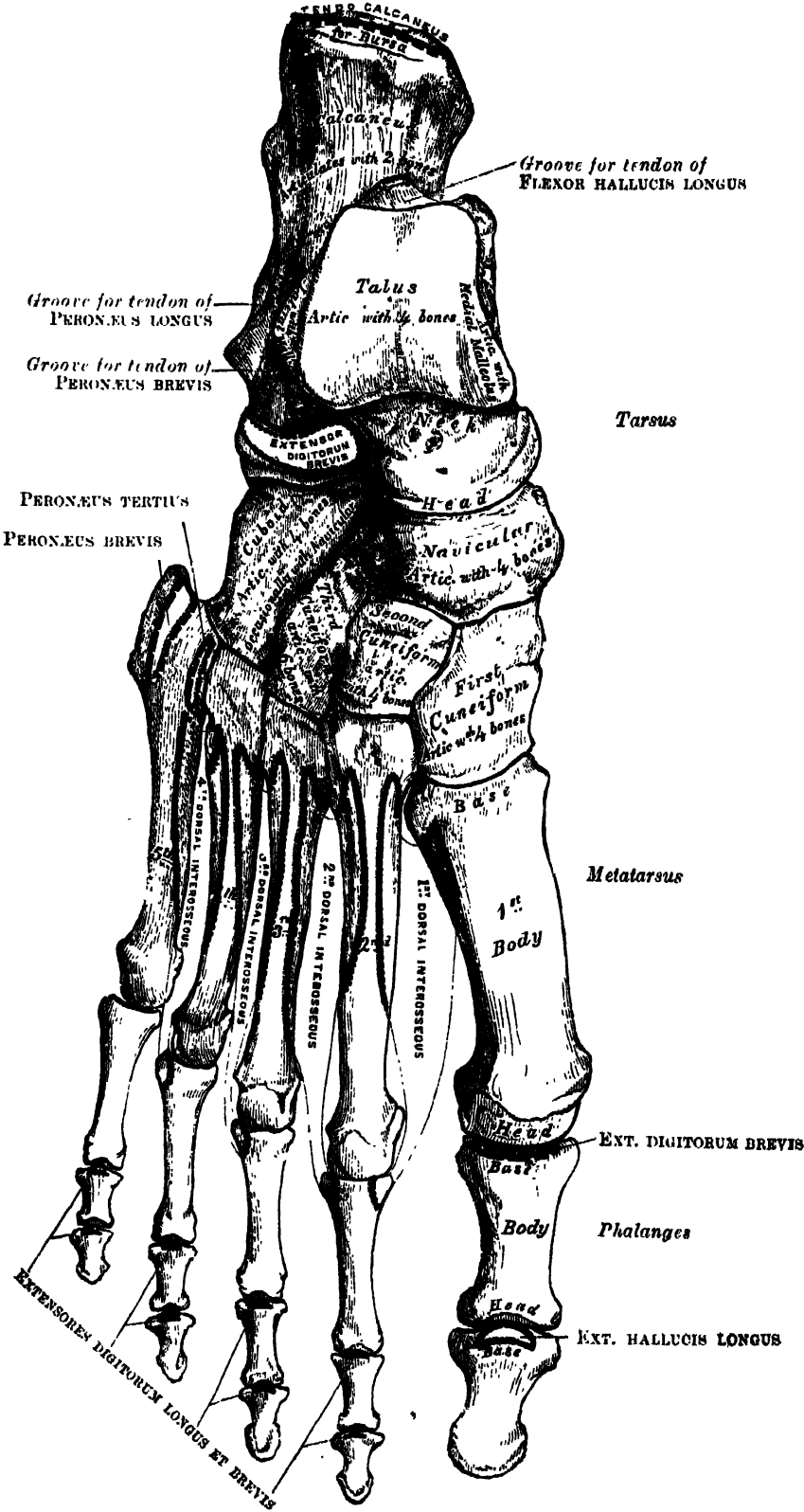
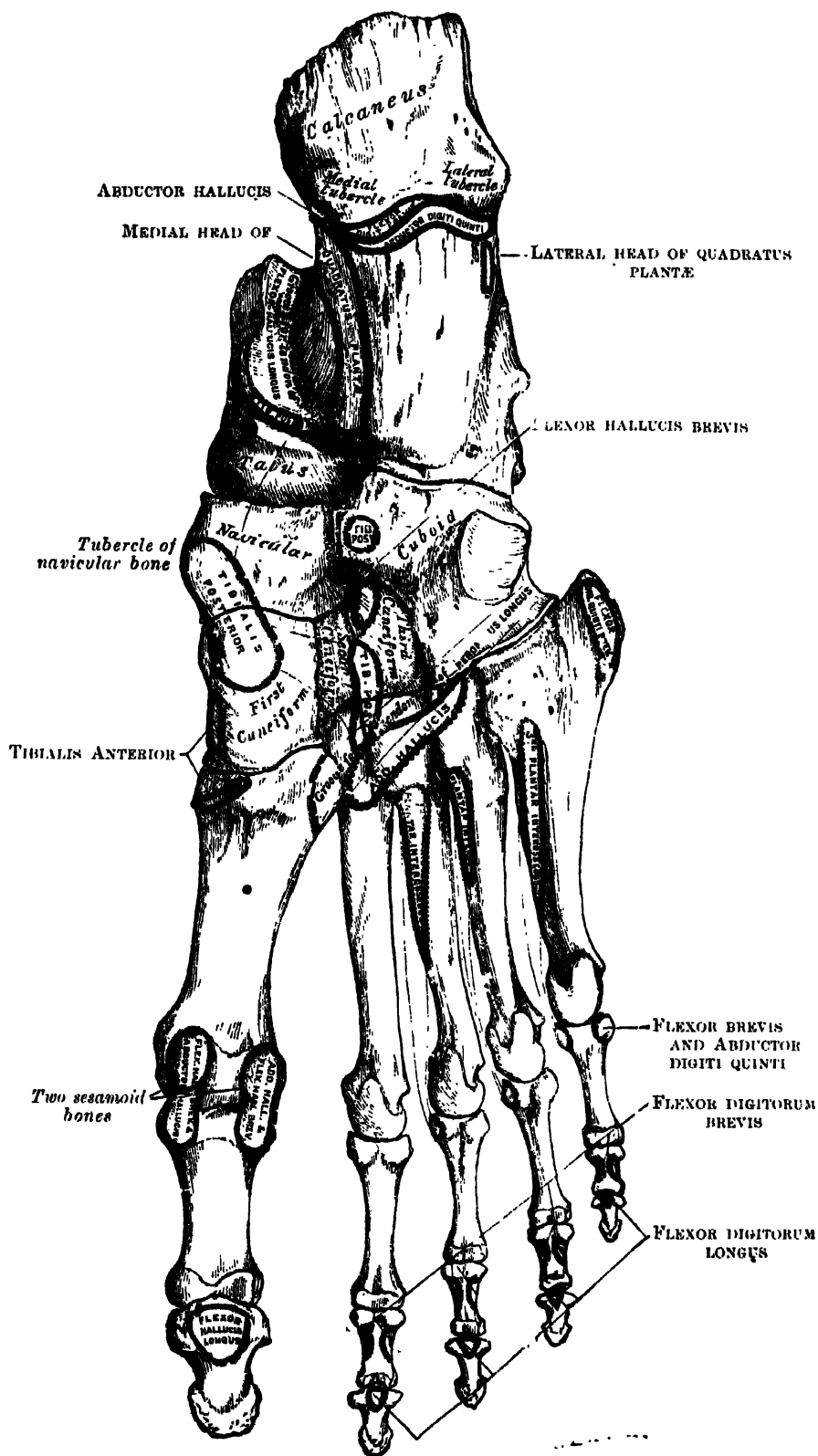


FIG. 428.—Bones of the right foot. Plantar surface.



THE TALUS (figs. 429 to 432)

The talus (astragalus), the second largest of the tarsal bones, supports the tibia and rests on the calcaneus; it articulates on either side with the

FIG. 429.—Left talus, from above.

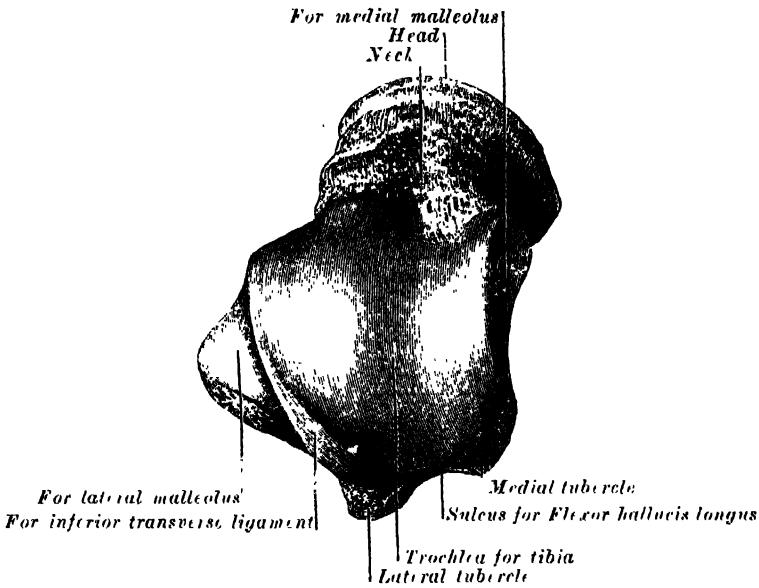
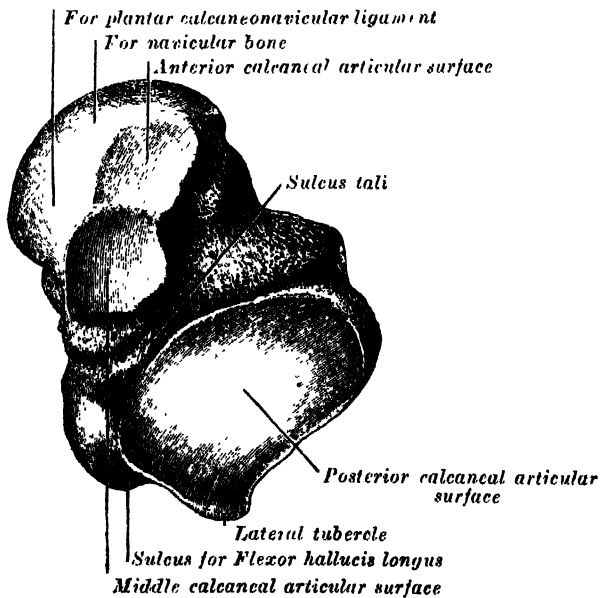


FIG. 430.—Left talus, from below



malleoli and in front with the navicular bone. It consists of a head, neck, body, and trochlea.

The head is directed forwards and medialwards. Its anterior or navicular surface is oval and convex, with its long axis running downwards and medialwards; it articulates with the concavity of the navicular bone. On the inferior surface of the head are three articular areas. The largest and hindmost,

termed the *middle calcaneal surface*, articulates with the upper surface of the sustentaculum tali. Anterior and lateral to this surface, and as a rule continuous with it, is the *anterior calcaneal surface*, quadrilateral or irregularly oval in shape, for articulation with the anterior part of the upper surface of the calcaneus. Sometimes the anterior and middle calcaneal articular surfaces are partly or wholly discontinuous. Medial to the anterior calcaneal surface is a triangular, convex area, which extends on to the medial side of the head; it rests on the inferior calcaneonavicular ligament and on the anterior part of the deltoid ligament of the ankle-joint.

The *neck* is the constricted part connecting the head with the body. Its *superior* and *medial* surfaces are rough and perforated by vascular foramina.

FIG. 431.—Left talus, medial surface.

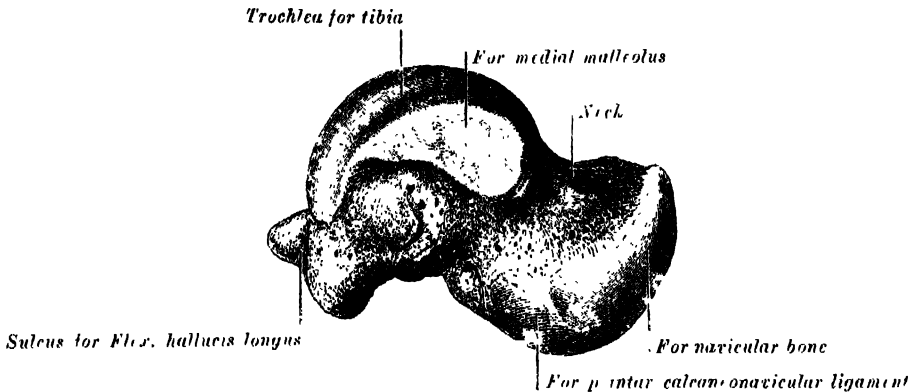
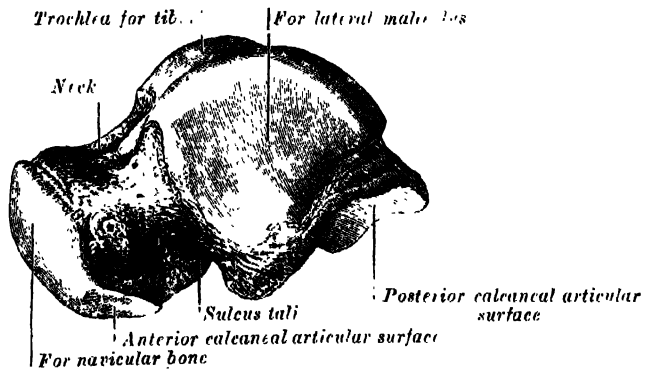


FIG. 432.—Left talus, lateral surface.



The superior surface gives attachment to the talonavicular ligament, and a depression on it, immediately in front of the superior surface of the trochlea, receives the anterior edge of the lower end of the tibia when the foot is flexed at the ankle-joint. The *lateral* surface is narrow, concave, and continuous with the *inferior* surface, which consists of the *sulcus tali*, a deep groove, wide in front and narrow behind, and directed forwards and lateralwards; in the articulated foot the sulcus tali overlies the sulcus calcanei and the two sulci form the *sinus tarsi*, a tunnel which is filled, in the recent condition, with the interosseous talocalcaneal ligament.

The *body* is the cuboidal posterior part of the bone, and from its upper surface the articular eminence termed the *trochlea* projects. The superior surface of the trochlea articulates with the lower end of the tibia; it is broader in front than behind, convex from before backwards, and slightly concave

from side to side. Its medial margin is straight, but its lateral is curved and inclines medialwards posteriorly where it usually expands into a small triangular facet * which comes into contact with the inferior transverse ligament of the ankle-joint during flexion of that articulation. The medial surface of the trochlea articulates with the medial malleolus: it is pear-shaped, with the blunt end directed forward. Below this surface is a rough, depressed area on the body for attachment of the deep part of the deltoid ligament of the ankle-joint. The lateral surface of the trochlea articulates with the lateral malleolus. It is concave vertically, triangular in outline with its apex downwards. Below the apex, the body projects as a rough, triangular eminence, named the *lateral process*; to it the lateral talocalcaneal ligament is attached. In front of the articular surface for the lateral malleolus is a rough impression for the anterior

FIG. 433.—Left calcaneus, superior surface.

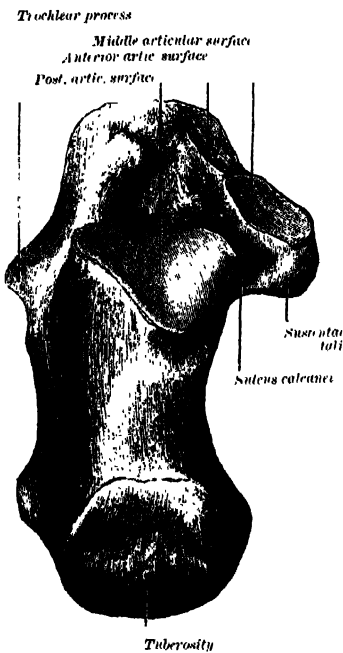
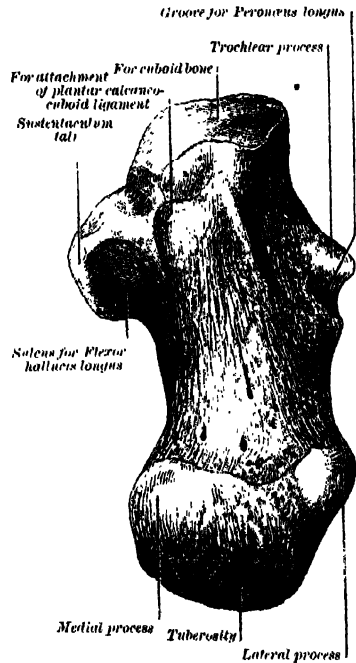


FIG. 434.—Left calcaneus, inferior surface.



talofibular ligament, while below and behind it is a groove in which a part of the posterior talofibular ligament is implanted.

On the *inferior* surface of the body is the *posterior calcaneal surface*, which is large in size and oval in form for articulation with the upper surface of the calcaneus. It is limited in front by the sulcus tali and is deeply concave in the direction of its long axis, which runs forwards and lateralwards at an angle of about 45° with the median plane.†

The *posterior* surface of the body is small, and projects backwards as the *posterior process*; it is traversed in a direction downwards and medialwards by a sulcus for the tendon of the Flexor hallucis longus. On either side of this sulcus is a tubercle. That on the lateral side is the more prominent and gives attachment to the main part of the posterior talofibular ligament; it is sometimes detached from the rest of the bone, and is then known as the *os trigonum*. To the smaller medial tubercle the medial talocalcaneal ligament is attached.

* Fawcett, *Edinburgh Medical Journal*, 1895.

† Sewell (*Journal of Anatomy and Physiology*, vol. xxxviii.) pointed out that in about 10 per cent. of bones a small triangular facet, continuous with the posterior calcaneal facet, is present at the junction of the lateral surface of the body with the posterior wall of the sulcus tali.

THE CALCANEUS (figs. 433 to 436)

The **calcaneus** (os calcis) is the largest of the tarsal bones. It is situated at the lower and back part of the foot, serving to transmit the weight of the body to the ground, and forming a strong lever for the muscles of the calf. It is irregularly cuboidal in form, having its long axis directed forwards and lateralwards.

The *superior surface* (fig. 433) consists of a posterior non-articular and an anterior articular part. The former varies in length in different individuals, is convex from side to side, concave from before backwards, and supports a

FIG. 435.—Left calcaneus, lateral surface.

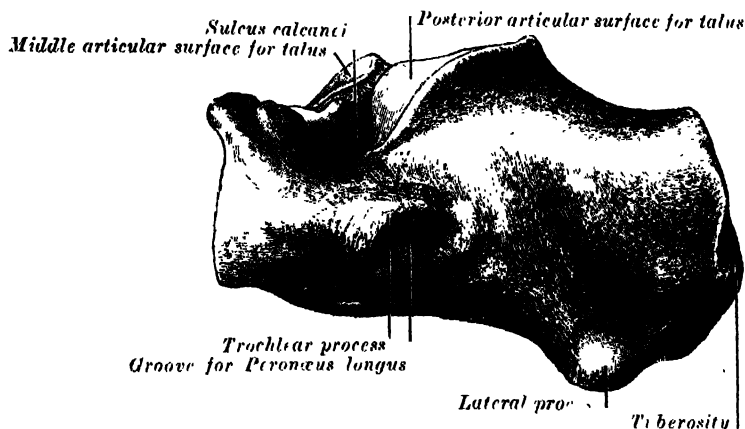
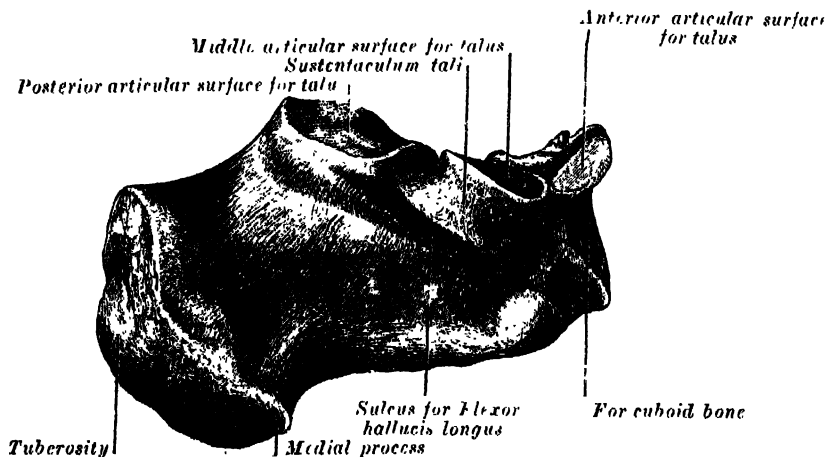


FIG. 436.—Left calcaneus, medial surface.



mass of fat placed in front of the tendo calcaneus. In front of this area is the *posterior articular surface*, a large, usually somewhat oval-shaped facet, which looks upwards and forwards: it is convex from behind forwards, and articulates with the posterior calcaneal facet on the under surface of the talus. It is bounded anteriorly by a deep depression which is continued backwards and medialwards in the form of a groove, the *sulcus calcanei*; in the articulated foot this sulcus lies below the sulcus tali, and the two sulci form a tunnel (*sinus tarsi*) for the lodgment of the interosseous talocalcaneal ligament. In front and to the medial side of this sulcus is an elongated facet, concave from behind forwards, and with its long axis directed forwards and lateralwards. This facet is frequently divided into two parts: of these, the posterior and larger is termed the *middle articular surface*; it is supported on a projecting process of bone, the *sustentaculum tali*, and articulates with the middle calcaneal facet on the under surface of the talus; the anterior and lesser, termed the

anterior articular surface, is placed on the anterior part of the body, and articulates with the anterior calcaneal facet on the under surface of the talus. The upper surface, anterior and lateral to the facets, is rough for the attachment of ligaments and for the origin of the *Extensor digitorum brevis*.

The *inferior or plantar surface* (fig. 434) is uneven, wider behind than in front, and convex from side to side; it is bounded posteriorly by the lower part of the calcaneal tuberosity, which presents a medial and a lateral process; the *lateral process*, small, prominent, and rounded, gives origin to part of the *Abductor digiti quinti*; the *medial process*, broader and larger, gives attachment, by its prominent medial margin, to the *Abductor hallucis*, and in front to the plantar aponeurosis and the *Flexor digitorum brevis*; the depression between the processes gives origin to the *Abductor digiti quinti*. The rough surface in front of the processes gives attachment to the long plantar ligament, and the lateral head of the *Quadratus plantæ*; to a prominent tubercle near the anterior part of this surface and to a transverse groove in front of the tubercle, the plantar calcaneocuboid ligament is attached.

The *lateral surface* (fig. 435) is broad behind, and narrow in front, flat and almost subcutaneous; near its centre is a small tubercle, for the attachment of the calcaneofibular ligament. Below and in front of this tubercle is a ridge, the *trochlear process* (peroneal tubercle), which is often indistinctly marked. It gives attachment to the inferior peroneal retinaculum, and separates two grooves; the superior groove transmits the tendon of the *Peronæus brevis*; the inferior, that of the *Peronæus longus*.

The *medial surface* (fig. 436) is directed obliquely downwards and forwards, and is deeply concave; above the anterior part of the concavity is a horizontal eminence, the *sustentaculum tali*. The superior surface of this eminence is concave, and articulates with the middle calcaneal articular surface of the talus; its inferior surface is grooved for the tendon of the *Flexor hallucis longus*; its anterior margin gives attachment to the plantar calcaneonavicular ligament, and its medial margin to a part of the deltoid ligament of the ankle joint.

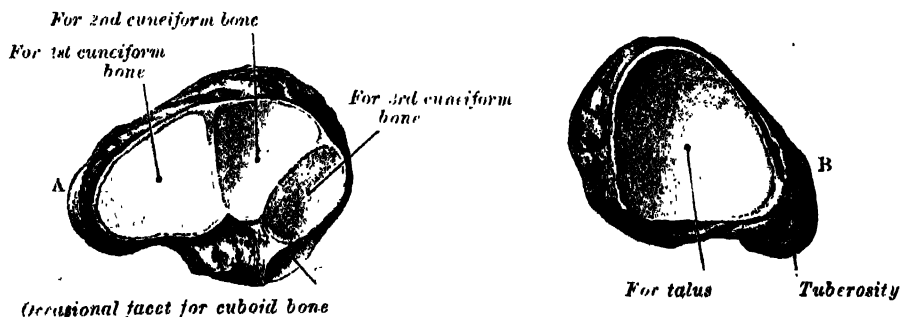
The *anterior extremity or cuboid articular surface* is of a somewhat triangular form. It is concave from above downwards and lateralwards, and convex in a direction at right angles to this. Its medial border gives attachment to the plantar calcaneonavicular ligament.

The *posterior extremity or calcaneal tuberosity* is prominent, convex, wider below than above, and divisible into three areas. The lowest of these is rough, and covered by the fatty and fibrous tissue of the heel; the middle, also rough, gives insertion to the tendo calcaneus and *Plantaris*; while the highest is smooth, and is covered by a bursa which intervenes between this part of the tuberosity and the tendo calcaneus. The plantar surface of this tuberosity displays the medial and lateral processes already described.

THE NAVICULAR BONE (OS NAVICULARE PEDIS)

The *navicular bone* (fig. 437) is situated at the medial side of the tarsus, between the talus behind and the cuneiform bones in front.

FIG. 437.—The left navicular bone. A. Anterolateral view. B. Posteromedial view.



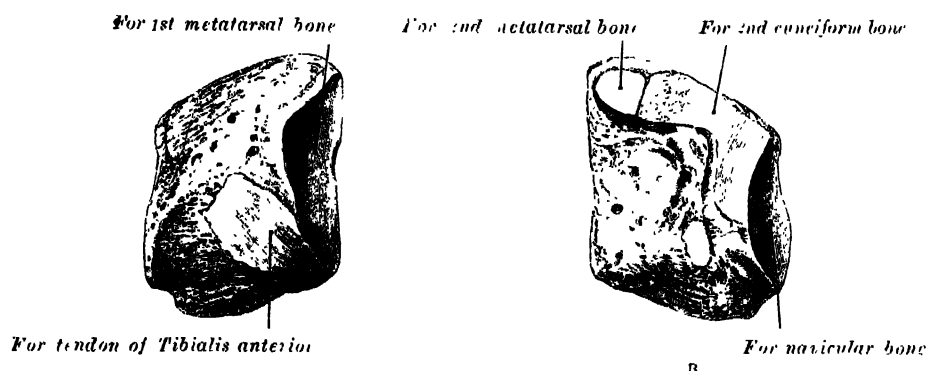
The *anterior surface* is convex from side to side, and subdivided by two ridges into three facets, for articulation with the three cuneiform bones. The

posterior surface, oval and concave, articulates with the rounded head of the talus. The *dorsal surface* is convex from side to side, and rough for the attachment of ligaments. The *plantar surface*, irregularly concave, displays on its lateral part a downward projection of varying size, the *plantar process*, to which a portion of the plantar calcaneonavicular ligament is attached. The *medial surface* consists of a rounded *tuberosity*, the lower part of which gives insertion to a large part of the tendon of the Tibialis posterior. Between the tuberosity and the plantar process is a well-marked groove for the lodgment of a part of the tendon of the Tibialis posterior. The *lateral surface* is rough and irregular for the attachment of ligaments, and frequently presents a facet for articulation with the cuboid bone.

THE CUNEIFORM BONES

The **cuneiform bones**, three wedge-shaped bones, articulate with the navicular bone behind and with the first, second, and third metatarsal bones in front; the first cuneiform bone is the largest, and the second the smallest.

FIG. 438.—The left first cuneiform bone.



In the articulated foot the posterior surfaces of the three cuneiform bones form a slight concavity for the navicular, but the anterior portions of the first and third project in front of the anterior surface of the second and form with it a deep recess in which the base of the second metatarsal bone is lodged.

The **first cuneiform bone** (*os cuneiforme primum*) (fig. 438), the largest, is situated at the medial side of the foot, between the navicular bone behind and the base of the first metatarsal bone in front and has the thin end of the wedge directed upwards.

The *medial surface* is subcutaneous, broad and quadrilateral; at its anterior plantar angle is a smooth oval impression, into which a part of the tendon of the Tibialis anterior is inserted. The *lateral surface* is concave; along its superior and posterior borders is a narrow L-shaped surface, the vertical limb and posterior part of the horizontal limb of which articulate with the second cuneiform bone, while the anterior part of the horizontal limb articulates with the second metatarsal bone; the facet for the second metatarsal bone is occasionally separated by a groove from that for the second cuneiform bone. The rest of this surface is rough for the attachment of ligaments and part of the tendon of the Peronæus longus. The *anterior surface*, large and kidney-shaped, articulates with the base of the first metatarsal bone. The *posterior surface*, triangular and concave, articulates with the medial facet on the anterior surface of the navicular bone. The *plantar surface* forms the base of the wedge; at its posterior part is a tuberosity for the insertion of part of the tendon of the Tibialis posterior; in front of this a part of the tendon of the Tibialis anterior is inserted. The *dorsal surface* is the thin end of the wedge, and is directed upwards and lateralwards; it is rough for the attachment of ligaments.

The **second cuneiform bone** (*os cuneiforme secundum*) (fig. 439), the smallest, is of very regular wedge-like form, the thin end being directed down-

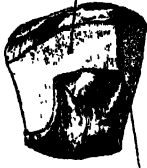
wards. It is situated between the first and third cuneiform bones, and articulates with the navicular bone behind, and the second metatarsal bone in front.

The *anterior surface*, triangular in form, articulates with the base of the second metatarsal bone. The *posterior surface*, also triangular, articulates with the intermediate facet on the anterior surface of the navicular bone. On the *medial surface* is an L-shaped facet, running along the superior and posterior borders, for articulation with the first cuneiform bone; the rest of the surface is rough for the attachment of ligaments. The *lateral surface*

FIG. 439.—The left second cuneiform bone.

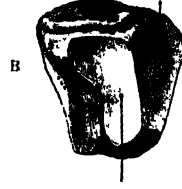
A. Anteromedial view. B. Posterolateral view.

For 1st cuneiform bone



For 2nd metatarsal bone

For navicular bone



For 3rd cuneiform bone

presents posteriorly a smooth facet for articulation with the third cuneiform bone. The *dorsal surface* or base of the wedge is quadrilateral and rough for the attachment of ligaments. The *plantar surface*, sharp and tuberculated, is also rough for the attachment of ligaments, and for the insertion of a slip from the tendon of the *Tibialis posterior*.

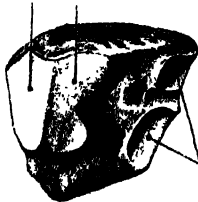
The **third cuneiform bone** (*os cuneiforme tertium*) (fig. 440), is intermediate in size between the first and second, and its base is directed upwards. It is placed between the second cuneiform and cuboid bones, and articulates with the navicular bone behind, and the third metatarsal bone in front.

The *anterior surface*, triangular in form, articulates with the base of the third metatarsal bone. The *posterior surface* articulates with the lateral facet on the anterior surface of the navicular bone, and is rough below for the attachment of ligamentous fibres. The *medial surface* presents an anterior and a posterior

FIG. 440.—The left third cuneiform bone.

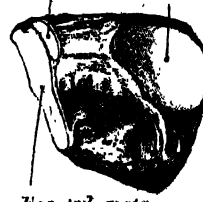
A. Posteromedial view. B. Anterolateral view.

For navicular bone For 2nd cuneiform bone



For 2nd metatarsal bone

For 4th metatarsal bone For cuboid bone



For 3rd metatarsal bone

articular facet: the anterior, sometimes divided, articulates with the lateral side of the base of the second metatarsal bone; the posterior skirts the posterior border, and articulates with the second cuneiform bone; the intervening rough area gives attachment to an interosseous ligament. The *lateral surface* also presents two articular facets; the anterior one, situated at the superior angle of the bone, is small and semi-oval in shape, and articulates with the medial side of the base of the fourth metatarsal bone; the posterior and larger one is triangular or oval, and articulates with the cuboid bone; the intervening, rough, non-articular area serves for the attachment of an interosseous ligament. The *dorsal surface* is of an oblong form, its posterolateral angle being prolonged backwards. The *plantar surface* is a rounded margin, and serves for

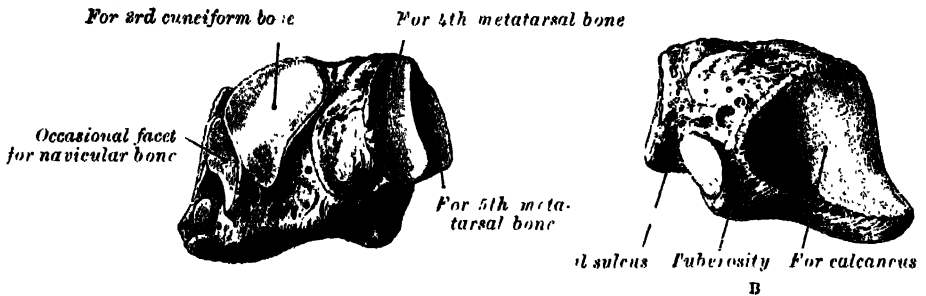
the attachment of ligaments and parts of the tendons of the *Tibialis posterior* and *Flexor hallucis brevis*.

THE CUBOID BONE (OS CUBOIDEUM)

The cuboid bone (fig. 441) is placed on the lateral side of the foot, in front of the calcaneus, and behind the fourth and fifth metatarsal bones.

The *dorsal surface*, directed upwards and lateralwards, is rough for the attachment of ligaments. The *plantar surface* is crossed in front by a deep groove, the *peronæal sulcus*, which runs obliquely forwards and medialwards; it lodges the tendon of the *Peronæus longus*, and is bounded behind by a prominent ridge, to which the long plantar ligament is attached. The ridge ends laterally in the *tuberosity*, the lateral part of which presents an oval facet: on this facet the sesamoid bone or cartilage which is frequently found in the tendon of the *Peronæus longus* glides. Behind the peronæal sulcus the bone is rough, for the attachment of the plantar calcaneocuboid ligament, a few fibres of the *Flexor hallucis brevis*, and a fasciculus from the tendon of the *Tibialis*.

FIG. 441.—The left cuboid bone. A. Antromedial view. B. Posterolateral view.



posterior. On the *lateral surface* is a deep notch formed by the commencement of the peronæal sulcus. The *posterior surface* is smooth, triangular, and concavoconvex, for articulation with the anterior surface of the calcaneus; its inferior, medial angle projects backwards as a process which underlies and supports the anterior end of the calcaneus. The *anterior surface* is divided by a vertical ridge into two facets; the medial, quadrilateral in form, articulates with the fourth metatarsal bone; the lateral, triangular, with the fifth. The *medial surface* is irregularly quadrilateral, and at its middle and upper part is a smooth oval facet, for articulation with the third cuneiform bone; behind this a small facet for articulation with the navicular bone is frequently present; the rest of this surface is rough for the attachment of interosseous ligaments.

THE METATARSUS

The *metatarsus* consists of five bones which are numbered from the medial side (ossa metatarsalia I-V); each has a body, a tarsal end or base, and a phalangeal end or head.

COMMON CHARACTERISTICS OF THE METATARSAL BONES

The *body* is prismoid in form; it tapers gradually from the base to the head, and is slightly convex longitudinally on its dorsal aspect. The *base* articulates proximally with the tarsus, and by its sides with the contiguous metatarsal bones. The *head* has a convex articular surface, which extends farther backwards below than above. Its sides are flattened, and on each is a depression, surmounted by a tubercle, for ligamentous attachment. Its *plantar surface* is marked on either side by an articular eminence continuous with the terminal articular surface.

CHARACTERISTICS OF THE INDIVIDUAL METATARSAL BONES

The first metatarsal bone (fig. 442) is the shortest and thickest of the metatarsal bones. The *body* is strong, and of well-marked prismoid form.

FIG. 442.—The first left metatarsal bone.

FIG. 443.—The second left metatarsal bone.

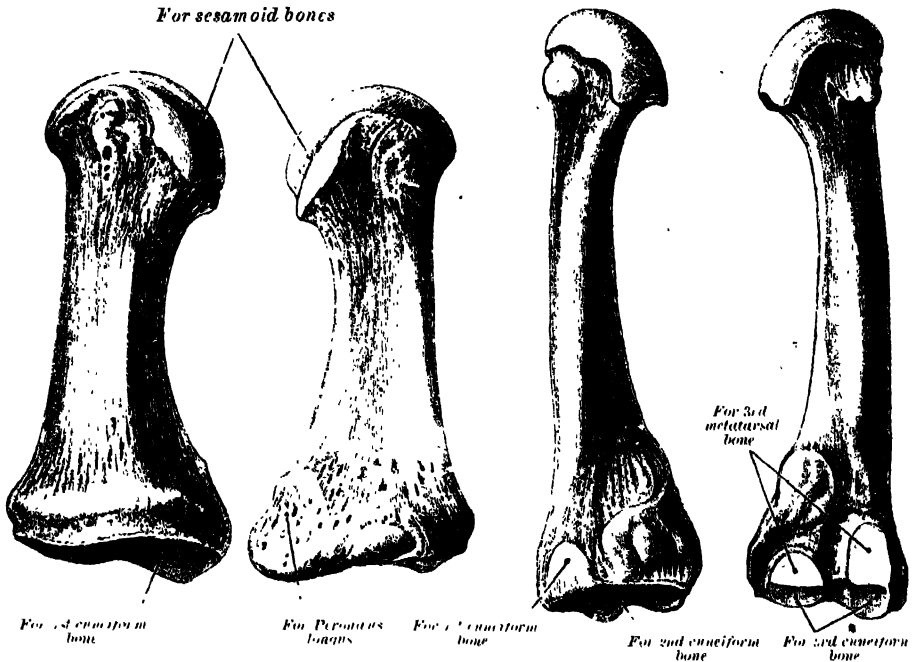
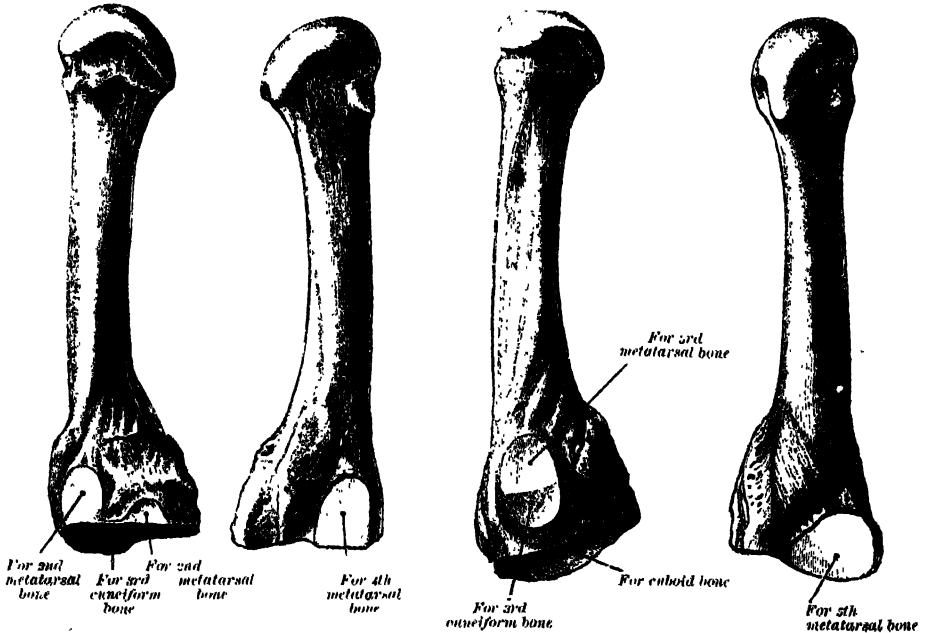


FIG. 444.—The third left metatarsal bone.

FIG. 445.—The fourth left metatarsal bone.



The *base* has, as a rule, no articular facets on its sides, but there is occasionally one on the lateral side for articulation with the second metatarsal bone. Its proximal articular surface, of large size and kidney-shaped, articulates with the

first cuneiform bone; its circumference is grooved, for the tarsometatarsal ligaments, and medially gives insertion to part of the tendon of the *Tibialis anterior*; its plantar angle presents a rough oval prominence for the insertion of the tendon of the *Peronæus longus*. The *head* is large; on its plantar surface is a median elevation separating two grooved facets, on which sesamoid bones glide.

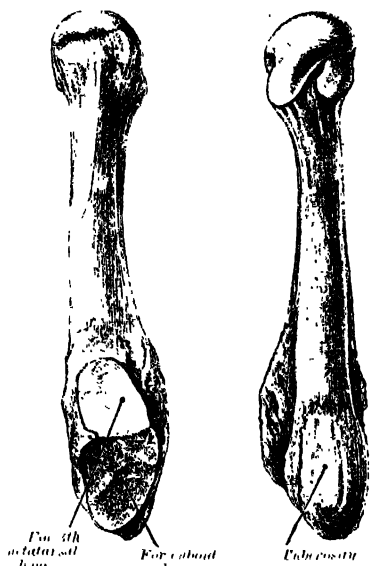
The **second metatarsal bone** (fig. 443) is the longest of the metatarsal bones. On its wedge-shaped *base* are four articular facets: one on its proximal surface, of a triangular form, for articulation with the second cuneiform bone; one at the upper part of its medial surface, for articulation with the first cuneiform bone; and two on its lateral surface, an upper and lower, separated by a rough non-articular interval. Each of these lateral articular surfaces is divided by a vertical ridge; the two anterior facets articulate with the third metatarsal bone; the two posterior (sometimes continuous) with the third cuneiform bone. A fifth facet is occasionally present for articulation with the first metatarsal bone; it is oval in shape, and is situated on the medial side of the base, distal to the facet for the first cuneiform bone.

The **third metatarsal bone** (fig. 444) has a triangular *base* which articulates proximally with the third cuneiform bone, medially it articulates by two facets with the second metatarsal bone; and laterally by a single facet, situated at the dorsal angle, with the fourth metatarsal bone.

FIG. 446.—The fifth left metatarsal bone.

The **fourth metatarsal bone** (fig. 445) is smaller than the third. Its *base* presents an oblique quadrilateral facet on its proximal surface for articulation with the cuboid bone; on the lateral side a single facet, for the fifth metatarsal bone; on the medial side a facet divided by a ridge into an anterior portion for the third metatarsal bone, and a posterior portion for the third cuneiform bone.

The **fifth metatarsal bone** (fig. 446) is recognised by a rough eminence, the *tuberosity*, on the lateral side of its base. The *base* articulates proximally, by a triangular, obliquely cut surface, with the cuboid bone; and medially, with the fourth metatarsal bone. On the medial part of its dorsal surface is inserted the tendon of the *Peronæus tertius*, and on the dorsal surface of the *tuberosity* that of the *Peronæus brevis*. A strong band of the plantar aponeurosis connects the projecting part of the *tuberosity* with the lateral process of the *tuberosity* of the calcaneus. The plantar surface of the base is grooved for the tendon of the *Abductor digiti quinti*, and gives origin to the *Flexor digiti quinti brevis*.



THE PHALANXES (PHALANXES DIGITORUM PEDIS)

The **phalanges** of the foot correspond in number and general arrangement with those of the hand: there are two in the great toe, and three in each of the other toes. They are, however, much smaller, and their bodies, especially those of the bones of the first row, are laterally compressed.

The phalanges of the **first row** closely resemble those of the hand. The *body* of each is compressed from side to side, convex above, concave below. The *base* is concave; and the *head* presents a trochlear surface for articulation with the second phalanx.

The phalanges of the **second row** are remarkably small and short, but rather broader than those of the first row.

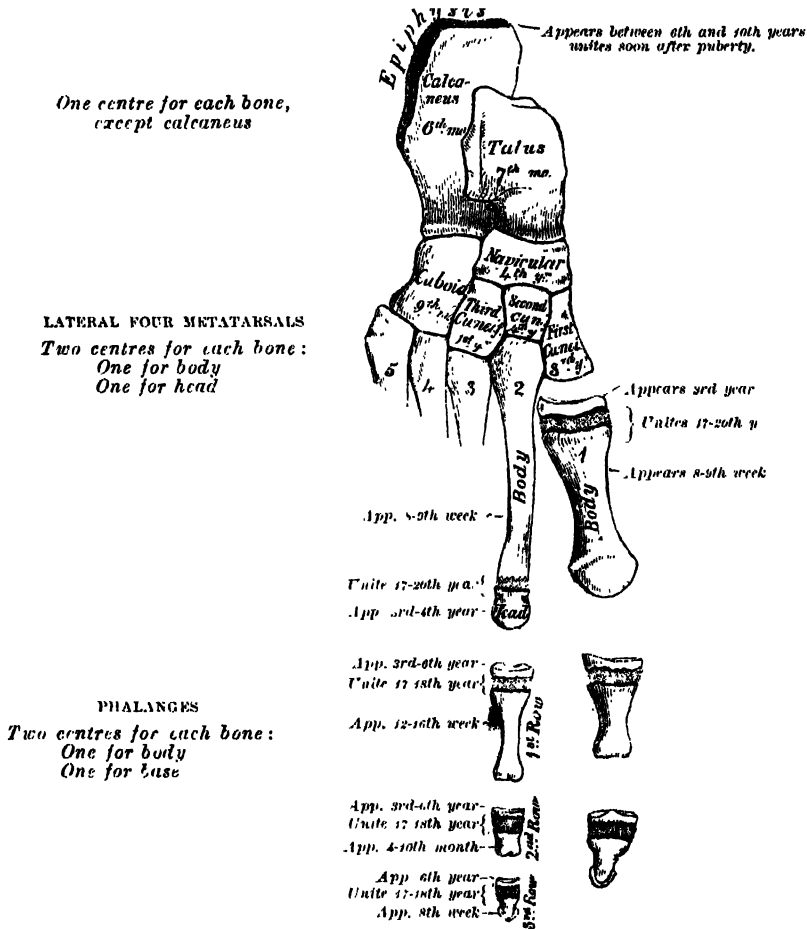
The **ungual phalanges** resemble those of the fingers; but they are smaller and are flattened from above downwards; each presents a broad base for

articulation with the corresponding bone of the second row, and an expanded distal extremity for the support of the nail and the end of the toe.

OSSIFICATION OF THE BONES OF THE FOOT (fig. 447)

The **tarsal bones** are each ossified from a single centre, excepting the calcaneus, which has an epiphysis for its tuberosity. The centres make their appearance in the following order: calcaneus, at the sixth month of foetal life; talus, about the seventh month; cuboid, at the ninth month; third cuneiform, during the first year; first cuneiform, in the third year; second cuneiform and navicular, in the

FIG. 447.—Plan of ossification of the foot.



fourth year. The epiphysis for the tuberosity of the calcaneus begins to ossify between the sixth and tenth years, and unites with the rest of the bone soon after puberty. The lateral tubercle of the posterior process of the talus is sometimes ossified from an independent centre, and may remain separate from the rest of the bone, when it is named the *os trigonum*.

The **metatarsal bones** are each ossified from two centres: a primary centre for the body, and an epiphysal centre for the proximal end of the first, and for the distal end of each of the other four.* Ossification commences in the body about the eighth or ninth week of foetal life. The epiphysis for the base of the

* As in the first metacarpal (see footnote, page 297), so in the first metatarsal, there is often a second epiphysis for the head.

first metatarsal appears about the third year; those for the heads of the other metatarsals between the third and fourth years; all join the bodies between the seventeenth and twentieth years.

The **phalanges** are each ossified from two centres: a primary one for the body and an epiphysis for the base. The primary centres for the ungual phalanges appear about the eighth week of foetal life; those for the first phalanges between the twelfth and sixteenth weeks, and those for the second phalanges after the sixteenth week (that for the second phalanx of the fifth toe does not usually appear until after birth). The epiphysial centres appear between the third and sixth years, and unite with the bodies about the seventeenth or eighteenth year.

COMPARISON OF THE BONES OF THE HAND AND FOOT

The hand and foot are constructed on somewhat similar principles, each consisting of a proximal part, the carpus (or tarsus), a middle portion, the metacarpus (or metatarsus), and a terminal portion, the phalanges. The proximal part consists of a series of more or less cubical bones which allow a slight amount of

FIG. 448.—Skeleton of foot. Medial aspect.

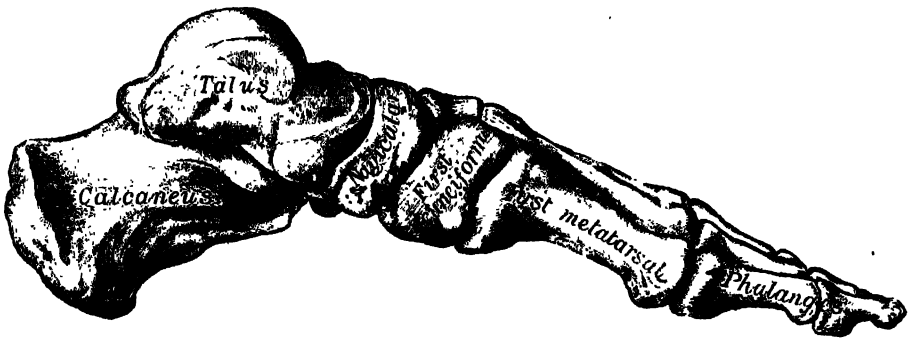


FIG. 449.—Skeleton of foot. Lateral aspect



gliding on one another and are chiefly concerned in distributing forces transmitted to or from the bones of the arm or leg. The middle part is made up of slightly movable long bones which assist the carpus or tarsus in distributing forces and also give greater breadth for the reception of such forces. The separation of the individual bones from one another allows of the attachments of the interosseous muscles and protects the dorsopalmar and dorsiplantar vascular anastomoses. The terminal portion is the most movable, and its separate elements enjoy a varied range of movements, the chief of which are flexion and extension.

The functions of the hand and foot are, however, very different, and the general similarity between them is greatly modified to meet these requirements. Thus the foot forms a firm basis of support for the body in the erect posture, and is therefore more solidly built, and its component parts are less movable on each other than

those of the hand. In the case of the phalanges the difference is readily noticeable; those of the foot are smaller and their movements more limited than those of the hand. Very much more marked is the difference between the metacarpal bone of the thumb and the metatarsal bone of the great toe. The metacarpal bone of the thumb is constructed to permit of great mobility; it is directed at an acute angle from that of the index finger, and is capable of a considerable range of movement at its articulation with the carpus. The metatarsal bone of the great toe assists in supporting the weight of the body, is constructed with great solidity, lies parallel with the other metatarsals, and has a very limited degree of mobility. The carpus is small in proportion to the rest of the hand, is placed in line with the forearm, and forms a transverse arch, the concavity of which constitutes a bed for the flexor tendons. The tarsus forms a considerable part of the foot, and is placed at right angles to the leg, a position which is almost peculiar to man, and has relation to his erect posture. In order to allow of their supporting the weight of the body with the least expenditure of material the tarsus and a part of the metatarsus are constructed in a series of arches (figs. 448 and 449), the disposition of which will be considered after the articulations of the foot have been described.

Applied Anatomy.—Considering the injuries to which the foot is subjected, it is surprising how seldom the tarsal bones are fractured. This is no doubt due to the fact that the tarsus is composed of a number of bones, articulated by a considerable extent of surface, and joined together by very strong ligaments which serve to break the force of violence applied to this part of the body. When fracture does occur, these bones being composed for the most part of a soft cancellous structure, covered only by a thin shell of compact tissue, are often extensively comminuted, especially as most of the fractures are produced by direct violence; and, as there is only a very scanty amount of soft parts over the bones, the fractures are very often compound, and amputation is often necessary.

When fracture occurs in the anterior group of tarsal bones, it is almost invariably the result of direct violence; but fractures of the posterior group—that is, of the calcaneus and talus—are usually produced by falls from a height on to the feet.

In club-foot (talipes), especially in congenital cases, the bones of the tarsus become altered in shape and size, and displaced from their proper positions. This is principally the case in congenital talipes equinovarus, in which the head of the talus becomes twisted and atrophied, and a similar condition may be present in the other bones, more especially the navicular. The tarsal bones are peculiarly liable to become the seat of tuberculous caries following comparatively trivial injuries, especially as they are not maintained in a condition of rest to the same extent as some other parts of the body after similar injuries. Caries of the calcaneus or talus may remain limited to the one bone for a long period, but when one of the other bones is affected, the remainder frequently become involved, since the disease spreads through the large and complicated synovial stratum which is more or less common to these bones.

Amputation of the foot is often required either for injury or disease. The principal amputations are as follows: (1) Syme's: amputation at the ankle-joint by a heel-flap, with removal of the malleoli and sometimes a thin slice from the lower end of the tibia. (2) Pirogoff's: amputation of the whole of the tarsal bones (except the posterior part of the calcaneus), and a thin slice from the tibia and fibula including the two malleoli. The sawn surface of the calcaneus is then turned up and united to the cut surface of the tibia. (3) Subastragalar: amputation of the foot below the talus through the joint between it and the calcaneus.

The bones of the tarsus occasionally require removal individually. This is especially the case with the talus for tuberculous disease limited to that bone; or the talus may require excision in cases of subastragalar dislocation, or in cases of inveterate talipes. The cuboid has been removed for the same reason.

Fractures of the metatarsal bones and phalanges are nearly always the result of direct violence, and in the majority of cases the injury is caused by severe crushing accidents, necessitating amputation. The metatarsal bones, and especially that of the great toe, are frequently diseased, either in tuberculous subjects or in patients with perforating ulcer of the foot.

SESAMOID BONES

Sesamoid bones are small more or less rounded masses of bone embedded in certain tendons and usually related to joint-surfaces. Their functions probably are to modify pressure, to diminish friction, and occasionally to alter the direction of the pull of a muscle. That they are not developed to meet certain physical requirements in the adult is evidenced by the fact that they are present as cartilaginous nodules in the foetus, and in greater numbers than in the adult. They must be regarded, according to Thilenius, as integral parts

of the skeleton phylogenetically inherited.* Physical necessities probably come into play in selecting and in regulating the degree of development of the original cartilaginous nodules.

Sesamoid bones are invested by the fibrous tissue of the tendons, except on the surfaces in contact with the parts over which they glide, where they present smooth articular facets.

In the upper extremity the sesamoid bones of the joints are found only on the palmar surface of the hand. Two, of which the medial is the larger, are constantly present at the metacarpophalangeal joint of the thumb; one is frequently present in the corresponding joint of the little finger, and one (or two) in the same joint of the index finger. Sesamoid bones are found occasionally at the metacarpophalangeal joints of the middle and ring fingers, at the interphalangeal joint of the thumb, and at the distal interphalangeal joint of the index finger.

In the lower extremity the largest sesamoid bone of the joints is the patella, developed in the tendon of the Quadriceps femoris. On the plantar aspect of the foot, two, of which the medial is the larger, are always present at the metatarsophalangeal joint of the great toe; one sometimes at the metatarsophalangeal joints of the second and fifth toes, one occasionally at the corresponding joints of the third and fourth toes, and one at the interphalangeal joint of the great toe.

Sesamoid bones apart from joints are seldom found in the tendons of the upper limb; one is sometimes seen in the tendon of the Biceps brachii opposite the radial tuberosity. They are, however, present in several of the tendons of the lower limb—viz. one in the tendon of the Peronæus longus, where it glides on the cuboid; one, appearing late in life, in the tendon of the Tibialis anterior, opposite the smooth facet of the first cuneiform bone; one in the tendon of the Tibialis posterior, opposite the medial side of the head of the talus; one in the lateral head of the Gastrocnemius, behind the lateral condyle of the femur; and one in the tendon of the Psoas major, where it glides over the os pubis. Sesamoid bones are found occasionally in the tendons which wind round the medial and lateral malleoli: one is sometimes present in the tendon of the Glutæus maximus where it passes over the greater trochanter.

* *Morpholog. Arbeiten*, v. 1906.

SYNDESMOLOGY

THE bones of the skeleton are connected to one another at different parts of their surfaces, and such connexions are termed *joints* or *articulations*. Where the joints are *immovable*, as in the articulations of the cranium, the opposed margins of the bones are nearly in contact, being separated merely by a thin layer of fibrous membrane, named the *sutural ligament*; in certain regions at the base of the skull this fibrous membrane is replaced by a layer of cartilage. Where *slight movement* combined with great strength is required, the opposed osseous surfaces are united by tough and elastic *fibrocartilages*, as in the joints between the vertebral bodies, and in the interpubic articulation. In the *freely movable* joints the opposed surfaces are completely separated from one another; the parts of the bones forming the articulations are expanded for greater convenience of mutual connexion, and are covered by hyaline cartilage, while the joints are enveloped by *articular capsules*, and are usually strengthened by strong fibrous bands called *ligaments*.

The extremities of the long bones are the parts which form the articulations; they are somewhat enlarged, and consist of spongy substance with a thin coating of compact substance. In the flat bones the articulations usually take place at the edges, and in the short bones at various parts of their surfaces. The layer of compact bone which forms the joint surface, and to which the articular cartilage is attached, is called the *articular lamella*; its lacunæ are large, but it contains no Haversian canals or canaliculi. The vessels of the spongy substance approach the articular lamella but do not perforate it; this lamella is consequently denser and firmer than ordinary bone.

Articular cartilage, which covers the articular surfaces of bones, and *fibrocartilage*, which enters into the structure of some of the joints, are described in the section on Histology (pp. 14 to 16).

Ligaments are composed mainly of parallel or closely interlaced bundles of *white fibrous tissue*, and present a silvery appearance. They are pliant and flexible, so as to allow perfect freedom of movement, but strong, tough, and inextensible, so as not to yield readily to applied force. Some ligaments consist entirely of *yellow elastic tissue*, as the *ligamenta flava* which connect together the laminae of adjacent vertebrae, and the *ligamentum nuchæ* in the lower animals. In these cases the elasticity of the ligament is intended to act as a substitute for muscular power.

The *articular capsules* form complete envelopes for the freely movable joints. Each capsule consists of two strata—an external (*stratum fibrosum*) composed of white fibrous tissue, and an internal (*stratum synoviale*) which secretes a lubricating fluid, and is sometimes described separately as the *synovial membrane*.

The *stratum fibrosum* is attached to the circumferences of the articular ends of the bones entering into the joint, and thus entirely surrounds the articulation.

The *stratum synoviale* invests the inner surface of the *stratum fibrosum*, is reflected over any tendons passing through the joint-cavity, and ceases at the margins of the articular cartilages. It is composed of a thin, delicate, connective tissue, and is covered on its free surface by a layer of endothelium. In some joints it is thrown into folds which pass across the cavity, as in the knee-joint; in others there are flattened folds, subdivided at their margins into fringe-like processes which contain convoluted vessels. These folds

generally project near the margin of the cartilage, and lie flat upon its surface. The stratum synoviale secretes a small quantity of thick, viscid fluid, termed *synovia*.

Closely related in structure and function to the synovial stratum of the articular capsule, and therefore conveniently described in this section, are the *vaginæ mucosæ* of tendons and the *bursæ mucosæ*.

Vaginæ mucosæ or mucous sheaths serve to facilitate the gliding of tendons in fibro-osseous canals, e.g. the tendons of the flexor and extensor muscles of the fingers and toes as they pass through fibro-osseous canals in or near the hand and foot. Each sheath is arranged in the form of an elongated closed sac, one layer of which adheres to the wall of the canal, and the other is reflected upon the surface of the enclosed tendon.

Bursæ mucosæ are interposed between surfaces which glide upon each other. They consist of closed sacs containing a minute quantity of clear viscid fluid, and may be grouped, according to their situations, under the headings *subcutaneous*, *submuscular*, *subfascial*, and *subtendinous*.

CLASSIFICATION OF JOINTS

Joints are divided into three classes: *synarthroses* or immovable, *amphiarthroses* or slightly movable, and *diarthroses* or freely movable.

1. SYNARTHROSES. (IMMOVABLE ARTICULATIONS)

Synarthroses are articulations in which the surfaces of the bones are fastened together by intervening connective tissue or hyaline cartilage, and in which there is no appreciable motion, as in the joints between the bones of the cranium. There are three varieties of synarthrosis: *sutura*, *gomphosis*, and *synchondrosis*.

Sutura is an articulation met with only in the skull, where the margins of the bones articulate with one another (fig. 450). The margins of the bones are not in direct contact, being separated by a thin layer of fibrous tissue, continuous externally with the *periosteum*, internally with the *dura mater*.

FIG. 450.—Section across the sagittal suture.

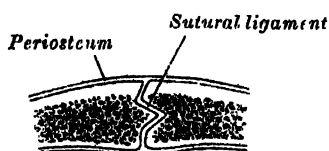
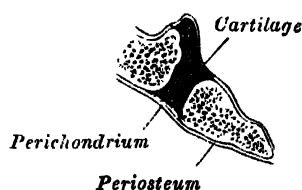


FIG. 451.—Section through occipitosphenoïdal synchondrosis of an infant.



When the bony margins are connected by a series of interlocking, tooth-like processes, the articulation is named a *sutura serrata*, as in the sagittal suture. When the articulation is formed by one bone overlapping another, as in the suture between the temporal and parietal bones, it is termed a *sutura squamosa*; where there is simple apposition of contiguous rough surfaces, as between the maxillæ, or the horizontal parts of the palatine bones, it is named a *sutura harmonia*.

Gomphosis is articulation by the insertion of a conical process into a socket; it is seen in the articulations of the roots of the teeth with the alveoli of the mandible and maxillæ.

Synchondrosis.—Where the connecting medium is cartilage the joint is termed a *synchondrosis* (fig. 451); this is a temporary form of joint, for the cartilage is ultimately converted into bone. Such joints are found between the epiphyses and bodies of long bones, between the occipital and the sphenoidal bone at and for some years after birth, and between the petrous portion of the temporal bone and the jugular process of the occipital bone.

2. AMPHIARTHROSES. (SLIGHTLY MOVABLE ARTICULATIONS)

In these articulations the contiguous bony surfaces are either united by an interosseous ligament, as in the inferior tibiofibular articulation, or are covered by articular cartilage and connected by broad flattened discs of fibrocartilage, of a more or less complex structure, as in the articulations between the bodies of the vertebræ. The first form is termed a **syndesmosis** the second a **symphysis** (fig. 452).

3. DIARTHROSES. (FREELY MOVABLE ARTICULATIONS)

This class includes the majority of the joints. In a diarthrodial joint the contiguous bony surfaces are covered with articular cartilage, and connected by an articular capsule and ligaments (*articulatio simplex*) (fig. 453). The joint may be divided, completely or incompletely, by an *articular disc*

FIG. 452.—Diagrammatic section of a symphysis.

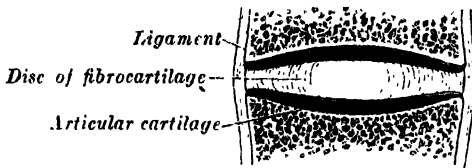


FIG. 453.—Diagrammatic section of a simple diarthrodial joint.

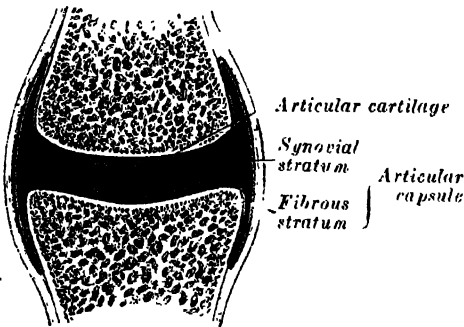
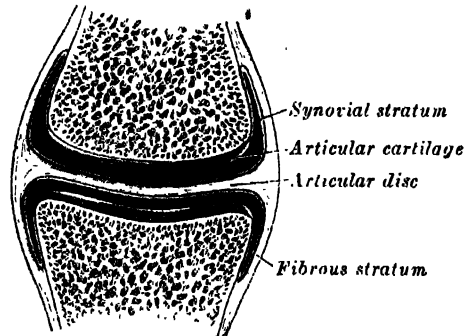


FIG. 454.—Diagrammatic section of a diarthrodial joint with an articular disc.



or *meniscus*, the periphery of which is continuous with the fibrous stratum of the articular capsule while its free surfaces are covered by the synovial stratum (*articulatio composita*) (fig. 454).

Joints of this class are subdivided according to the kind of motion permitted in them. There are two varieties in which the movement is uni-axial; that is to say, all movements take place around one axis. In one, the *ginglymus* or *hinge-joint*, this axis is, practically speaking, transverse; in the other, the *articulatio trochoidea* or *pivot-joint*, it is longitudinal. There are two varieties where the movement is bi-axial; these are the *articulatio ellipsoidea* or *condyloid joint* and the *articulatio sellaris* or *saddle-joint*. There is one form where the movement is poly-axial, the *articulatio sphaeroidea* or *enarthrosis* (*ball-and-socket joint*); and finally there is the *arthrodia* or *gliding joint*.

Ginglymus or hinge-joint.—In this form the articular surfaces are moulded to each other in such a manner as to permit motion only in one plane. The articular surfaces are connected together by strong collateral ligaments, which form their chief bond of union. The best examples of ginglymus are the interphalangeal joints and the joint between the humerus and ulna.

Trochoid articulation or pivot-joint.—Where the movement is limited to rotation, the joint is formed by a pivot-like process turning within a ring, or a

ring on a pivot, the ring being formed partly of bone, partly of ligament. In the proximal radio-ulnar articulation, the ring is formed by the radial notch of the ulna and the annular ligament; here, the head of the radius rotates within the ring. In the articulation of the dens of the epistropheus with the atlas, the ring is formed in front by the anterior arch, and behind by the transverse ligament, of the atlas; here, the ring rotates round the dens.

Condylod articulation.—In this form of joint, an ovoid articular surface, or condyle, is received into an elliptical cavity in such a manner as to permit of flexion, extension, adduction, abduction, and circumduction, but no axial rotation. The radiocarpal joint is an example of this form of articulation.

Saddle-articulation.—In this variety the opposing surfaces are reciprocally concavoconvex, and the movements are the same as in the preceding form. The best example of the saddle-articulation is the carpometacarpal joint of the thumb.

Enarthrosis is a joint in which the distal bone is capable of motion around an indefinite number of axes, which have one common centre. It is formed by the reception of a globular head into a cup-like cavity, hence the name 'ball-and-socket.' Examples of this form of articulation are found in the hip- and shoulder-joints.

Arthrodia is a joint which admits of only gliding movement; it is formed by the apposition of plane, or nearly plane, surfaces, the amount of motion in such joints being limited by the ligaments or osseous processes surrounding the articulations. It is the form present in the joints between the articular processes of the vertebræ, and in most of the carpal and tarsal joints.

THE KINDS OF MOVEMENT PERMITTED IN JOINTS

The movements permitted in joints may be divided into four kinds: gliding and angular movements, circumduction, and rotation. Frequently these are more or less combined in the various joints, so as to produce an infinite variety, and it is seldom that only one kind of motion is found in any particular joint.

Gliding movement is the simplest kind of motion that can take place in a joint, one surface gliding over another without any angular or rotatory movement. It is common to all movable joints; but in some, as in most of the articulations of the carpus and tarsus, it is the only motion permitted. This movement is not confined to plane surfaces, but may take place between any two contiguous surfaces, of whatever form.

Angular movement occurs only between the long bones, and by it the angle between the two bones is increased or diminished. It may take place: (1) forwards and backwards, constituting flexion and extension; or (2) towards and from the median plane of the body, or, in the case of the fingers or toes, from the middle line of the hand or foot, constituting adduction and abduction. The strictly ginglymoid or hinge-joints admit of flexion and extension only. Abduction and adduction, combined with flexion and extension, are met with in the more movable joints.

Circumduction is that form of motion which takes place between the head of a bone and its articular cavity, when the bone is made to circumscribe a conical space; the base of the cone is described by the distal end of the bone, the apex is in the articular cavity; this kind of motion is best seen in the shoulder- and hip-joints.

Rotation is a form of movement in which a bone moves round a longitudinal axis; the axis of rotation may lie in a separate bone, as in the case of the pivot formed by the dens of the epistropheus around which the atlas turns; or a bone may rotate around its own longitudinal axis, as in the rotation of the humerus at the shoulder-joint; or the axis of rotation may not be quite parallel to the long axis of the bone, as in the movement of the radius on the ulna during pronation and supination of the hand, where it is represented by a line connecting the centre of the head of the radius with the centre of the head of the ulna.

Ligamentous action of muscles.—The movements of the different joints of a limb are combined by means of the long muscles passing over more than one joint. These muscles, when relaxed and stretched to their greatest extent, act as elastic ligaments in restraining certain movements of one joint, except when combined with

corresponding movements of the other—the latter movements being usually in the opposite direction. Thus the shortness of the hamstring muscles prevents complete flexion of the hip, unless the knee-joint is also flexed so as to bring their attachments nearer together. The uses of this arrangement are threefold. 1. It co-ordinates the kinds of movements which are the most habitual and necessary, and enables them to be performed with the least expenditure of power. 2. It enables the short muscles which pass over only one joint to act upon more than one. 3. It provides the joints with ligaments which, while they are of very great power in resisting movements to an extent incompatible with the mechanism of the joint, at the same time spontaneously yield when necessary.

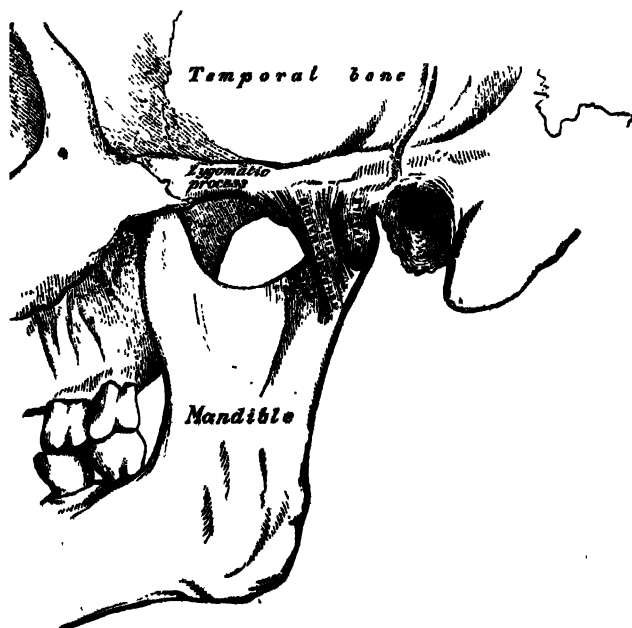
Applied Anatomy.—W. W. Keen points out how important it is 'that the surgeon should remember this ligamentous action of muscles in making passive motion—for instance, at the wrist after Colles's fracture. If the fingers be extended, the wrist can be flexed to a right angle. If, however, they be first flexed as in "making a fist," flexion at the wrist is quickly limited to from forty to fifty degrees in different persons, and is very painful beyond that point. Hence passive motion here should be made with the fingers extended. In the leg, when flexing the hip, the knee should be flexed.'

ARTICULATION OF THE MANDIBLE

The parts entering into the formation of this joint are : above, the articular tubercle, and the anterior portion of the mandibular fossa of the temporal bone; below, the condyle of the mandible. The ligaments of the joint are the following :

The articular capsule.	Sphenomandibular.
Temporomandibular.	The articular disc.
	Stylomandibular.

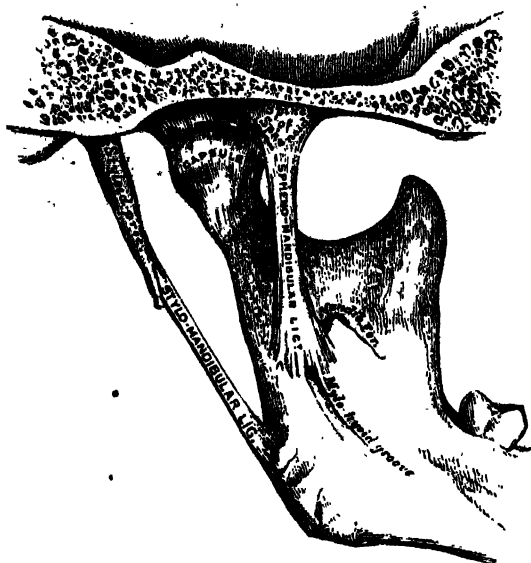
FIG. 455.—Articulation of the mandible. Lateral aspect.



The articular capsule is a thin, loose envelope, attached, above, to the circumference of the mandibular fossa and the articular tubercle; below, to the neck of the condyle of the mandible. The synovial stratum of the articular capsule is continued over the upper and lower surfaces of the articular disc.

The temporomandibular ligament (external lateral ligament) (fig. 455) consists of two short, narrow fasciculi, one in front of the other, attached, above,

FIG. 455.—Articulation of the mandible.
Medial aspect.



to the lateral surface of the zygomatic process of the temporal bone and to the tubercle on its lower border; below, to the lateral surface and posterior border of the neck of the mandible. It is broader above than below, and its fibres are directed obliquely downwards and backwards.

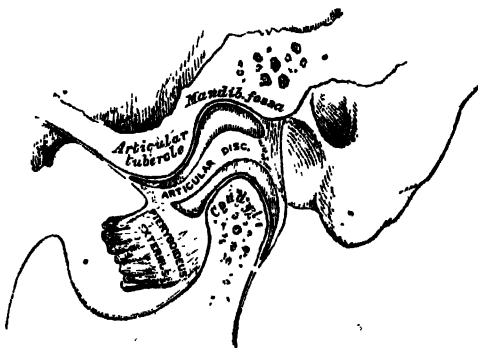
The sphenomandibular ligament (fig. 456) is a flat, thin band which is attached above to the spina angularis of the sphenoidal bone, and, becoming broader as it descends, is fixed to the lingula of the mandibular foramen.* Its lateral surface is in relation, above, with the Pterygoideus externus; lower down, it is separated from the neck of the condyle by the internal maxillary vessels; still lower, the inferior alveolar vessels and nerve and a lobule of the

parotid gland lie between it and the ramus of the mandible. Its medial surface is in relation with the Pterygoideus internus.

The articular disc (fig. 457) is a thin, oval plate, placed between the condyle of the mandible and the mandibular fossa; it divides the joint into two cavities. Its upper surface is concavoconvex from before backwards, to accommodate itself to the form of the mandibular fossa and the articular tubercle. Its under surface, in contact with the condyle, is concave. Its circumference is connected to the articular capsule, and in front to the tendon of the Pterygoideus externus. It is thicker at its periphery, especially behind, than at its centre, where it is sometimes perforated. The fibres of which it is composed have a concentric arrangement, more apparent at the circumference than at the centre.

The stylomandibular ligament (fig. 456) is a specialised band of the fascia colli, which stretches from the apical part of the styloid process of the temporal bone to the angle and posterior border of the ramus of the mandible between the Masseter and Pterygoideus internus. It separates the parotid from the submaxillary gland, and from its deep surface some fibres of the Styloglossus take origin.

FIG. 457.—Sagittal section of the articulation of the mandible.



* J. Cameron (*Journal of Anatomy and Physiology*, vol. xlix.) points out that the cranial end of this ligament 'enters the inner extremity of the Glaserian fissure and whilst doing so is merely attached to the spine of the sphenoid by its inner edge.' He suggests that the attachment to the spina angularis of the sphenoidal bone is purely adventitious, and that the true morphological attachment is in reality to the lips of the fissure and also within the tympanic cavity, where a considerable proportion of the fibres are directly continuous with the fibrous layer of the membrane tympani. This intratympanic portion is usually described as the anterior ligament of the malleus. It forms a prominent band in a seven months fetus, and at this stage appears to be independent of the sphenoidal bone.

Although classed among the ligaments of the temporomandibular joint, it can only be considered as accessory to it.

The *nerves* of the temporomandibular joint are derived from the auriculo-temporal and masseteric branches of the mandibular nerve, the *arteries* from the superficial temporal branch of the external carotid artery, and from the internal maxillary artery.

Movements.—The movements permitted in this articulation are extensive. Thus, the mandible may be depressed or elevated, or carried forwards or backwards; a slight amount of side-to-side movement is also permitted. When the mouth is opened the body of the mandible is depressed, and the condyles and articular discs are pulled forwards on to the articular tubercles; in shutting the mouth the reverse action takes place. When the mandible is carried horizontally forwards, as in protruding the lower incisor teeth in front of the upper, the disc and the condyle glide forwards on the mandibular fossa and articular tubercle. The grinding or chewing movement is produced by one condyle, with its disc, gliding alternately forwards and backwards, while the other condyle moves simultaneously in the opposite directions; at the same time the condyle undergoes a vertical rotation on the disc. One condyle advances and rotates, while the other recedes and rotates.

The mandible is *depressed* by its own weight, assisted by the *Platysma*, and, when the hyoid bone is fixed by the *Digastricus*, the *Mylohyoideus*, and the *Geniohyoideus*; at the same time the condyles and the articular discs are drawn forwards by the *Pterygoidei externi*. It is *elevated* by the *Masseter*, *Pterygoideus internus*, and *Temporalis*. It is drawn *forwards* by the simultaneous action of the *Pterygoidei internus* and *externus*, the superficial fibres of the *Masseter* and the anterior fibres of the *Temporalis*; and *backwards* by the deep fibres of the *Masseter* and the posterior fibres of the *Temporalis*. The grinding movement is caused by the alternate action of the *Pterygoidei* of either side.

Applied Anatomy.—The mandible can be dislocated only in one direction—viz. forwards. The accident is caused by violence or by muscular action. When the mouth is open, the condyle is situated on the articular tubercle, and any sudden violence, or even a sudden muscular spasm, as during a convulsive yawn, may displace the condyle forwards into the infratemporal fossa. The displacement may be unilateral or bilateral. Reduction is accomplished by depressing the jaw with the thumbs placed on the last molar teeth, and at the same time elevating the chin. The downward pressure overcomes the spasm of the *Masseter*, *Temporalis*, and *Pterygoideus internus*, and elevation of the chin throws the condyle backwards; the above-mentioned muscles then draw the condyle back into its normal position.

In close relation to the condyle of the mandible are the external acoustic meatus and the tympanic cavity; any force, therefore, applied to the bone is liable to be attended with damage to these parts, or inflammation in the joint may extend to them. On the other hand inflammation of the tympanic cavity may involve the articulation and cause its destruction, thus leading to ankylosis of the joint. The joint is also occasionally the seat of osteo-arthritis, causing great suffering during efforts of mastication. A peculiar affection sometimes attacks the neck and condyle of the mandible, consisting in hypertrophy and elongation of these parts and consequent protrusion of the chin to the opposite side.

ARTICULATIONS OF THE VERTEBRAL COLUMN

The vertebræ from the third cervical to the first sacral inclusive are articulated to one another by: (1) a series of amphiarthrodial joints between the vertebral bodies; and (2) a series of diarthrodial joints between the vertebral arches.

1. ARTICULATIONS OF VERTEBRAL BODIES

The articulations between the bodies of the vertebræ are amphiarthrodial joints, and the individual vertebræ move only slightly on each other. When, however, this slight degree of movement between the pairs of bones takes

place in a considerable length of the vertebral column, the total range of movement is great. The ligaments of these articulations are the following :

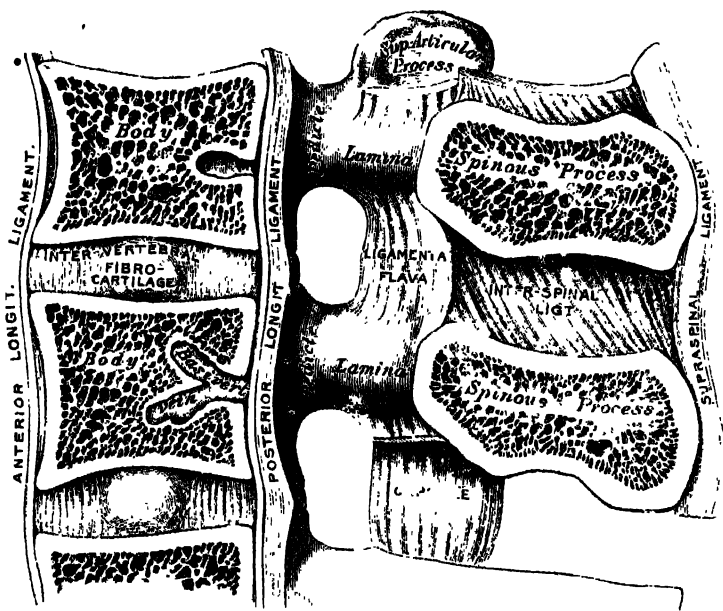
Anterior longitudinal.

Posterior longitudinal.

Intervertebral fibrocartilages.

The **anterior longitudinal ligament** (fig. 466) is a broad and strong band of fibres, which extends along the anterior surfaces of the bodies of the vertebræ. It is broader below than above, thicker and narrower in the thoracic than in the cervical and lumbar regions, and somewhat thicker and narrower opposite the bodies of the vertebræ than opposite the intervertebral fibrocartilages. It is attached above, to the pharyngeal tubercle of the occipital bone, whence it extends to the anterior tubercle of the atlas, then to the front of the body of the epistropheus, and is continued down as far as the upper part of the front of the sacrum. It consists of dense longitudinal fibres, which are intimately adherent to the intervertebral fibrocartilages and the prominent

FIG. 458.—Median sagittal section of two lumbar vertebræ and their ligaments.



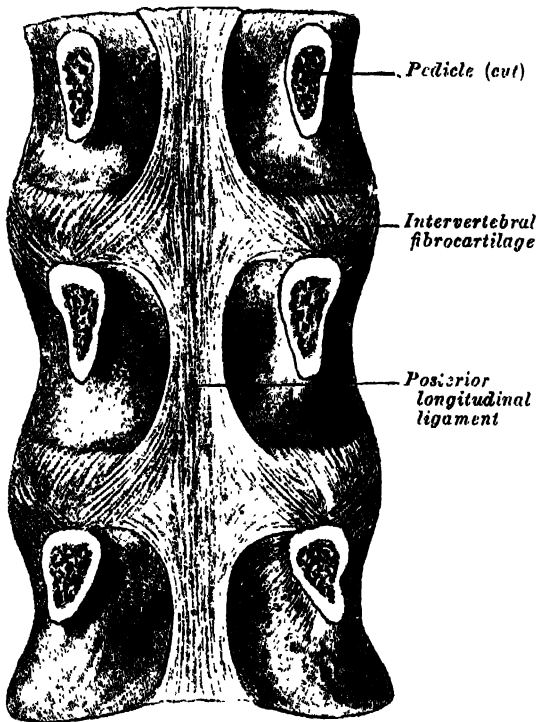
margins of the vertebræ, but not to the middle parts of the vertebral bodies. In the latter situation the ligament is thick and fills up the concavities on the anterior surfaces, and makes the front of the vertebral column more even. It is composed of several layers of fibres, of which the most superficial are the longest and extend between four or five vertebræ. The intermediate fibres extend between two or three vertebræ, while the deepest reach from one vertebra to the next. At the sides of the bodies the ligament consists of a few short fibres which pass from one vertebra to the next, separated from the concavities of the vertebral bodies by apertures for the passage of vessels.

The **posterior longitudinal ligament** (figs. 458, 459) is situated within the vertebral canal on the posterior surfaces of the bodies of the vertebræ. Above, it is attached to the basilar part of the occipital bone, and extends down, in intimate connexion with the membrana tectoria, to the body of the epistropheus, and is thence continued downwards to the sacrum. It is broader above than below, and thicker in the thoracic than in the cervical and lumbar regions. In the situation of the intervertebral fibrocartilages and contiguous margins of the vertebræ, where the ligament is more intimately adherent, it is broad, and in the thoracic and lumbar regions presents a series of dentations with intervening concave margins; but it is narrow and thick over the centres of the bodies, from which it is separated by the basivertebral veins.

This ligament is composed of smooth, shining fibres, denser and more compact than those of the anterior ligament, and consists of superficial layers occupying the interval between three or four vertebræ, and deeper layers which extend between adjacent vertebræ.

The intervertebral fibrocartilages (figs. 458, 459) are interposed between the adjacent surfaces of the bodies of the vertebræ, from the epistropheus to the sacrum, and form the chief bonds of connexion between the vertebræ.

FIG. 459.—Posterior longitudinal ligament of vertebræ, in lumbar region.



Their shape corresponds with that of the bodies between which they are placed. Their thickness varies in different regions of the column, and in different parts of the same fibrocartilage; they are thicker in front than behind in the cervical and lumbar regions, and thus contribute to the anterior convexities of these parts of the column; while they are of nearly uniform thickness in the thoracic region, the anterior concavity of this part of the column being almost entirely due to the shape of the vertebral bodies. They are adherent, by their surfaces, to thin layers of hyaline cartilage which cover the upper and under surfaces of the bodies of the vertebræ; in the lower cervical vertebræ, however, small joints with articular capsules are occasionally present between the upper surfaces of the bodies and the margins of the fibrocartilages on either side.

The intervertebral fibrocartilages are closely connected to the anterior and posterior longitudinal ligaments; in the thoracic region they are joined laterally, by means of the interarticular ligaments, to the heads of those ribs which articulate with two vertebræ. The intervertebral fibrocartilages constitute about one-fourth of the length of the vertebral column, exclusive of the first two vertebræ; but this amount is not equally distributed between the various bones, the cervical and lumbar portions having, in proportion to their length, a much greater amount than the thoracic region, with the result that these parts possess greater pliancy and freedom of movement.

Structure of the intervertebral fibrocartilages.—Each is composed, at its circumference, of laminae of fibrous tissue and fibrocartilage, forming the *annulus fibrosus*; and, at its centre, of a soft, pulpy, highly elastic substance, of a yellowish colour, which projects considerably above the surrounding level when the disc is divided horizontally. This pulpy substance (*nucleus pulposus*), especially well developed in the lumbar region, contains the remains of the notochord. The laminae are arranged concentrically; the outermost consist of ordinary fibrous tissue, the others of white fibrocartilage. The laminae are not quite vertical in their direction, those near the circumference being curved outwards and closely approximated; while those nearest the centre curve in the opposite direction, and are somewhat more widely separated. The fibres of which each lamina is composed are directed, for the most part, obliquely from above downwards, the fibres of adjacent laminae passing in opposite directions and varying in every layer: so that the fibres of one layer are directed across those of another, like the limbs of the letter X. This laminar arrangement exists in about the outer half of each fibrocartilage. The pulpy substance presents no such arrangement, and consists of a fine fibrous matrix, containing angular cells united to form a reticular structure.

Applied Anatomy.—When an aneurysm presses on the vertebral column, the vertebral bodies are often deeply eroded by it, while the intervertebral fibrocartilages remain intact. The fibrocartilages are the first to be destroyed, however, in tuberculosis of the vertebral column, where, as not infrequently happens, the disease begins in the fibrocartilages, and spreads thence to the bodies of the two adjoining vertebrae.

2. ARTICULATIONS OF VERTEBRAL ARCHES

The joints between the articular processes of the vertebrae belong to the arthrodial variety and are enveloped by articular capsules; while the laminae, spinous and transverse processes are connected by the following ligaments:

Ligamenta flava.
Supraspinal.

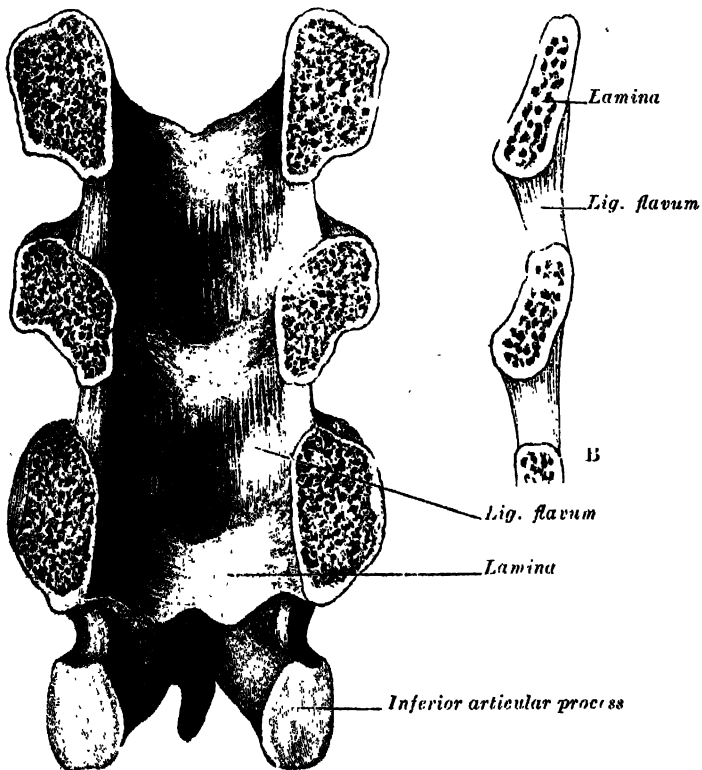
Ligamentum nuchae.
Interspinal.

Intertransverse.

The articular capsules (fig. 458) are thin and loose, and are attached to the margins of the articular processes of adjacent vertebrae; they are longer and looser in the cervical than in the thoracic and lumbar regions.

The ligamenta flava (fig. 460) connect the laminae of adjacent vertebrae, and are best seen from the interior of the vertebral canal. Their attachment

FIG. 460.—Ligamenta flava. A. from behind. B. in section.



extends from the articular capsules to the point where the laminae fuse to form the spinous process; here their posterior margins come into contact and are to a certain extent united, small intervals being left for the passage of vessels. The ligamenta flava consist of yellow elastic tissue, the fibres of which, almost perpendicular in direction, are attached to the anterior surface of the lamina above, some distance from its inferior margin, and to the posterior surface and upper margin of the lamina below. The ligaments are thin, but broad and long in the cervical region; they are thicker in the thoracic region,

and thickest in the lumbar region. Their marked elasticity serves to preserve the upright posture, and to assist the vertebral column in resuming it after flexion.

The **supraspinal ligament** (fig. 458) is a strong fibrous cord, which connects together the apices of the spinous processes from the seventh cervical vertebra to the sacrum; fibrocartilage is developed in the ligament at its points of attachment to the tips of the spinous processes. It is thicker and broader in the lumbar than in the thoracic region, and intimately blended in both situations with the neighbouring fascia. The most superficial fibres of this ligament extend over three or four vertebræ; those more deeply seated pass between two or three vertebræ; while the deepest connect the spinous processes of neighbouring vertebræ. Between the spinous processes it is continuous with the interspinal ligaments. (Between the spinous process of the seventh cervical vertebra and the external occipital protuberance its place is taken by the *ligamentum nuchæ*.)

The **ligamentum nuchæ** is a fibrous membrane, which, in the neck, represents the supraspinal ligament of the thoracic and lumbar vertebræ. It extends from the external protuberance and median nuchal line of the occipital bone to the spinous process of the seventh cervical vertebra. From its anterior border a fibrous lamina is given off, which is attached to the posterior tubercle of the atlas, and to the spinous processes of the cervical vertebræ, and forms a septum between the muscles on either side of the neck. In man it is the representative of an important elastic ligament, which, in some of the lower animals, serves to sustain the weight of the head.

The **interspinal ligaments** (fig. 458). thin and membranous, connect adjoining spinous processes, and their attachments extend from the root to the apex of each process. They meet the ligamenta flava in front and the supraspinal ligament behind. They are narrow and elongated in the thoracic region; broader, thicker, and quadrilateral in form in the lumbar region; and only slightly developed in the neck.

The **intertransverse ligaments** are interposed between the transverse processes. In the cervical region they consist of a few irregular, scattered fibres; in the thoracic region they are rounded cords intimately connected with the deep muscles of the back; in the lumbar region they are thin and membranous.

3. SACROCOCCYGEAL SYMPHYSIS

This articulation is an amphiarthrodial joint, between the apex of the sacrum and the base of the coccyx. It is homologous with the joints between the bodies of the vertebræ, and is connected by the following ligaments:

Anterior sacrococcygeal.	Lateral sacrococcygeal.
Posterior sacrococcygeal.	Fibrocartilaginous disc.

The **anterior sacrococcygeal ligament** consists of a few irregular fibres, which descend from the anterior surface of the sacrum to the front of the coccyx, blending with the periosteum.

The **posterior sacrococcygeal ligament** is a flat band, which arises from the margin of the lower orifice of the sacral canal, and descends to be inserted into the posterior surface of the coccyx. This ligament completes the lower and back part of the sacral canal, and is divisible into a short *deep* and a longer *superficial* part.

A **lateral sacrococcygeal ligament** exists on either side and connects the transverse process of the coccyx to the lower lateral angle of the sacrum; it completes the foramen for the fifth sacral nerve.

A thin disc of **fibrocartilage** is interposed between the contiguous surfaces of the sacrum and coccyx; it is somewhat thicker in front and behind than at the sides. Occasionally the coccyx is freely movable on the sacrum; in such cases an articular capsule lined by a synovial stratum is present.

The different segments of the coccyx are connected together by the extension downwards of the anterior and posterior sacrococcygeal ligaments, thin annular discs of fibrocartilage being interposed between the segments. In the adult

male, all the pieces become ossified together at a comparatively early period ; but in the female, this does not commonly occur until a later period of life. At a more advanced age the joint between the sacrum and coccyx is obliterated. Backward and forward movements take place between the sacrum and coccyx ; their extent increases during pregnancy.

Movements.—The movements permitted in the vertebral column are : flexion, extension, lateral movement, circumduction, and rotation.

In *flexion*, or movement forwards, the anterior longitudinal ligament is relaxed and the anterior parts of the intervertebral fibrocartilages are compressed ; while the posterior longitudinal ligament, the ligamenta flava, and the inter- and supraspinal ligaments are stretched, as well as the posterior fibres of the intervertebral fibrocartilages. The interspaces between the laminae are widened, and the inferior articular processes glide upwards upon the superior articular processes of the subjacent vertebrae. Flexion is the most extensive of all the movements of the vertebral column, and is freest in the lumbar region.

In *extension*, or movement backwards, an exactly opposite disposition of the parts takes place. This movement is limited by the anterior longitudinal ligament, and by the approximation of the spinous processes. It is freest in the cervical region.

In *lateral movements*, the sides of the intervertebral fibrocartilages are compressed, the extent of motion being limited by the resistance offered by the surrounding ligaments. Lateral movements may take place in any part of the column, but are freest in the cervical and lumbar regions.

Circumduction is very limited, and is merely a succession of the preceding movements.

Rotation is produced by the twisting of the intervertebral fibrocartilages ; this, although only slight between any two vertebrae, allows of a considerable extent of movement when it takes place in the whole length of the column, the front of the upper part of the column being turned to one or other side. This movement occurs to a slight extent in the cervical region, is freer in the upper part of the thoracic region, and absent in the lumbar region.

The extent and variety of the movements are influenced by the shape and direction of the articular surfaces. In the *cervical* region the upward inclination of the superior articular surfaces allows of free flexion and extension. Extension can be carried farther than flexion ; at the upper end of the region it is checked by the locking of the posterior edges of the superior atlantal facets in the condyloid fossae of the occipital bone ; at the lower end it is limited by a mechanism whereby the inferior articular processes of the seventh cervical vertebra slip into grooves behind and below the superior articular processes of the first thoracic. Flexion is arrested just beyond the point where the cervical convexity is straightened ; the movement is checked by the apposition of the projecting lower lips of the bodies of the vertebrae with the shelving surfaces on the bodies of the subjacent vertebrae. Lateral flexion and rotation are free in the cervical region, and are always combined : the upward and medial inclinations of the superior articular surfaces impart a rotatory movement during lateral flexion.

In the *thoracic* region, notably in its upper part, all the movements are limited in order to reduce interference with respiration to a minimum. The almost complete absence of an upward inclination of the superior articular surfaces prohibits any marked flexion, while extension is checked by the contact of the inferior articular margins with the laminae, and the contact of the spinous processes with one another. Rotation is free in the thoracic region : the superior articular processes are segments of a cylinder whose axis is in the mid-ventral line of the vertebral bodies. The direction of the articular facets would allow of free lateral flexion, but this movement is considerably limited in the upper part of the region by the resistance of the ribs and sternum.

In the *lumbar* region flexion and extension are free. The inferior articular facets are not in close apposition with the superior facets of the subjacent vertebrae, and on this account a considerable amount of lateral flexion is permitted. For the same reason a slight amount of rotation can be carried out, but this is so soon checked by the interlocking of the articular surfaces that it is negligible.

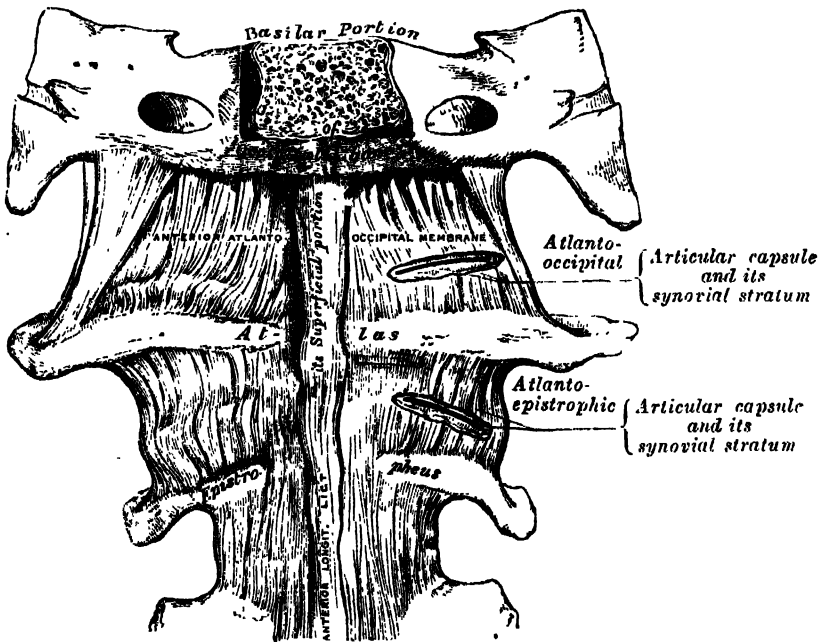
The principal muscles which produce *flexion* are the Sternocleidomastoides, Longus capitis and Longus colli, the Scalenii, the abdominal muscles, and the Psoas major. *Extension* is produced by the intrinsic muscles of the back, assisted in the

neck by the Splenius, Semispinales dorsi and cervicis, and the Multifidus. *Lateral* motion is produced by the intrinsic muscles of the back, by the Splenius, the Scaleni, the Quadratus lumborum, and the Psoas major, the muscles of one side only acting ; and *rotation* by the action of the following muscles of one side only, viz. the Sternocleidomastoideus, the Longus capitis, the Scaleni, the Multifidus, the Semispinalis capitis, and the abdominal muscles.

4. ARTICULATION OF THE ATLAS WITH THE EPISTROPHEUS

The articulation of the atlas with the epistropheus is of a complicated nature and comprises three joints. There is a pivot articulation between the dens of the epistropheus and the ring formed by the anterior arch and

FIG. 461.—Anterior atlanto-occipital membrane.



the transverse ligament of the atlas (see fig. 463), and a pair of arthrodial or gliding joints between the articular processes of the two bones. The ligaments connecting these bones are :

Two articular capsules.

Transverse.

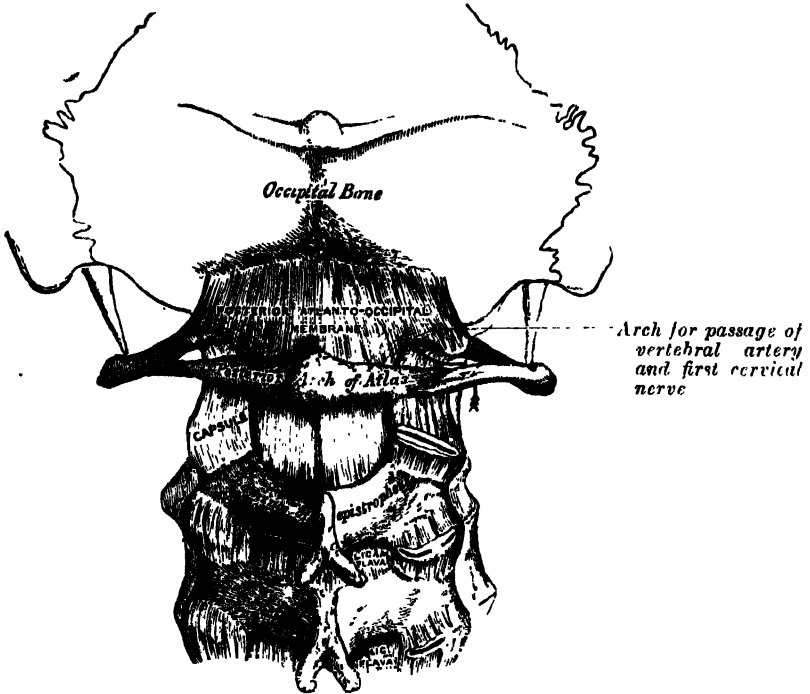
The articular capsules are thin and loose, and surround the joints between the articular surfaces of the bones. Each is strengthened at its posterior and medial part by an *accessory ligament*, which is attached below to the body of the epistropheus near the base of the dens, and above to the lateral mass of the atlas near the transverse ligament.

In front, the two vertebræ are connected by a continuation of the anterior longitudinal ligament (fig. 461). In this position it is a strong membrane, fixed, above, to the lower border of the anterior arch of the atlas, and below, to the front of the body of the epistropheus. It is strengthened in the middle line by a rounded cord, which connects the tubercle on the anterior arch of the atlas to the body of the epistropheus.

Behind, the atlas and epistropheus are joined by a broad, thin membrane (fig. 462) attached, above, to the lower border of the posterior arch of the atlas, below, to the upper edges of the laminæ of the epistropheus ; it is in series with the ligamenta flava.

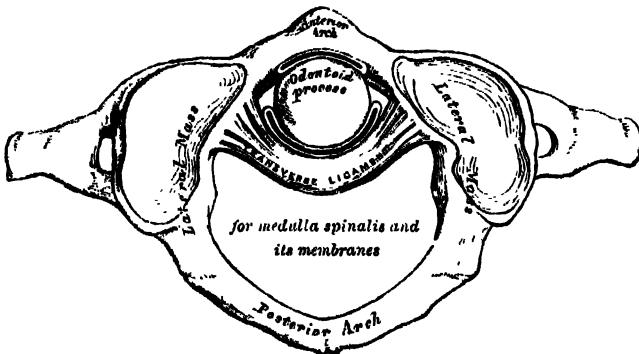
The transverse ligament of the atlas (figs. 463, 464, 465) is a thick, strong band, which arches across the ring of the atlas, and retains the dens of the epistropheus in contact with the anterior arch. It is concave in front,

FIG. 462.—Posterior atlanto-occipital membrane.



convex behind, broader in the middle than at the ends, and firmly attached on either side to a small tubercle on the medial surface of the lateral mass of the atlas. As it crosses the dens, a small fasciculus (*crus superius*) is prolonged upwards, and another (*crus inferius*) downwards, from the superficial or posterior fibres of the ligament. The former is attached to the basilar part of the occipital bone in close relation with the membrana tectoria; the latter

FIG. 463.—Articulation between the dens and the atlas.



is fixed to the posterior surface of the body of the epistropheus; hence the whole ligament is named the *ligamentum cruciatum atlantis*. The transverse ligament divides the ring of the atlas into two unequal parts: of these, the posterior and larger serves for the transmission of the medulla spinalis and its membranes and the spinal parts of the accessory nerves; the anterior and

FIG. 464.—Membrana tectoria, transverse, and alar ligaments. The crus superius of the transverse ligament is drawn to one side.

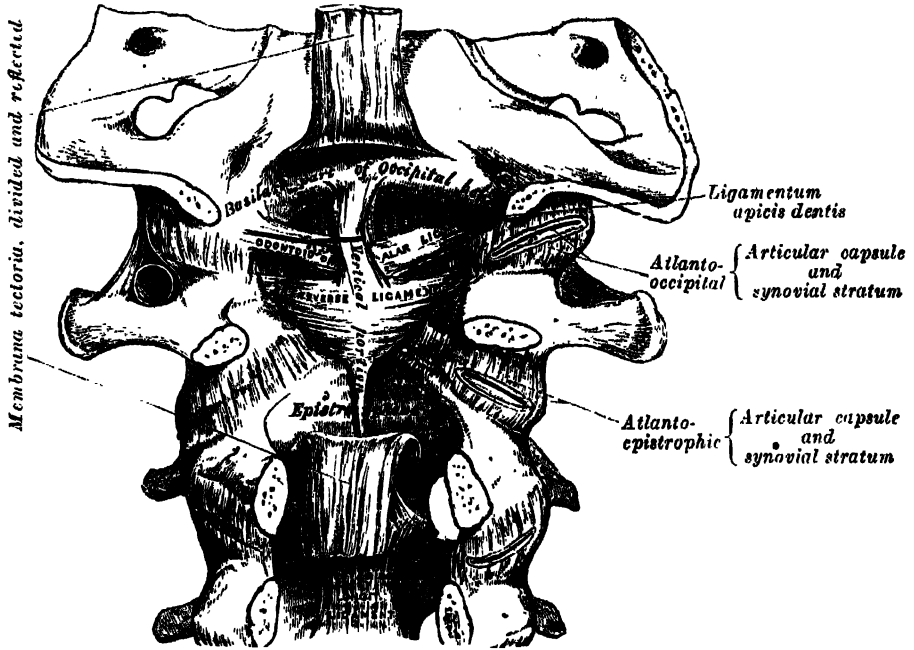
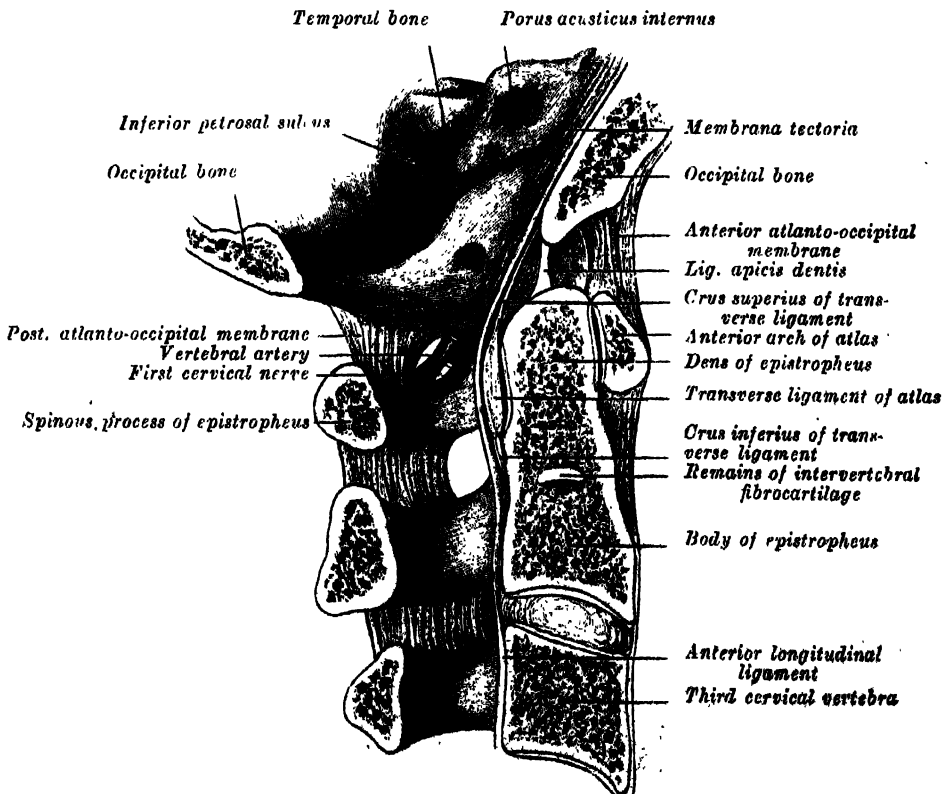


FIG. 465.—Median sagittal section through the occipital bone and first three cervical vertebrae.



smaller contains the dens. The neck of the dens is constricted where it is embraced posteriorly by the transverse ligament, so that this ligament suffices to retain the process in position after all the others have been divided.

The joint-cavity between the dens and the transverse ligament is often continuous with those of the atlanto-occipital articulations.

Movements.—This articulation with its three joints allows the rotation of the atlas (and, with it, the skull) upon the epistropheus, the extent of rotation being limited by the alar ligaments.

The opposed surfaces of the articular processes of the atlas and epistropheus are not reciprocally curved; both are convex in their long axes. When, therefore, the upper facet glides forwards on the lower it also descends; the fibres of the articular capsule are relaxed in a vertical direction, and will then permit of movement in an anteroposterior direction. By this means a shorter capsule suffices and the strength of the joint is materially increased.

The principal muscles by which these movements are produced are the Sternocleidomastoideus and Semispinalis capitis of one side, acting with the Longus capitis, Splenius, Longissimus capitis, Rectus capitis posterior major, and Obliquus capitis inferior of the other side.

ARTICULATIONS OF THE VERTEBRAL COLUMN WITH THE CRANIUM

The ligaments connecting the vertebral column with the cranium may be divided into two sets; those uniting the atlas with the occipital bone, and those connecting the epistropheus with the occipital bone

1. ARTICULATION OF THE ATLAS WITH THE OCCIPITAL BONE

The articulation between the atlas and the occipital bone consists of a pair of condyloid joints. The ligaments connecting the bones are:

Two articular capsules.	Posterior atlanto-occipital
Anterior atlanto-occipital membrane.	membrane.

The articular capsules surround the condyles of the occipital bone, and connect them with the articular processes of the atlas: they are thin and loose. Their lateral portions are directed obliquely upwards and medialwards, and are reinforced by bundles of fibres, which are attached above to the jugular processes of the occipital bone, and below to the bases of the transverse processes of the atlas.

The atlanto-occipital joints frequently communicate with the joint between the dens and the transverse ligament of the atlas.

The anterior atlanto-occipital membrane (fig. 461) is broad, and composed of densely woven fibres which pass between the anterior margin of the foramen magnum above, and the upper border of the anterior arch of the atlas below; laterally, it is continuous with the articular capsules; in front, it is strengthened in the middle line by the continuation of the anterior longitudinal ligament, a strong, rounded cord, which connects the basilar part of the occipital bone to the tubercle on the anterior arch of the atlas.

The posterior atlanto-occipital membrane (fig. 462), broad but thin, is connected, above, to the posterior margin of the foramen magnum; below, to the upper border of the posterior arch of the atlas. On either side it is defective below, over the groove for the vertebral artery, and forms with this groove an opening for the entrance of the artery and the exit of the first cervical nerve. The free border of the membrane, arching over the artery and nerve, is sometimes ossified.

Movements.—The movements permitted in this joint are (a) flexion and extension, which give rise to the ordinary forward and backward nodding of the head, and (b) slight lateral motion to one or other side. *Flexion* is produced mainly by the action of the Longi capitis and Recti capitis anteriores; *extension* by the Recti capitis posteriores major and minor, the Obliquus superior, the Semispinalis capitis, Splenius capitis, Sternocleidomastoideus, and upper fibres of the Trapezius. The Recti laterales are concerned in the lateral movement, assisted by the Trapezius,

Splenius capitis, Semispinalis capitis, and the Sternocleidomastoides of the same side, all acting together.

2. LIGAMENTS CONNECTING THE EPISTROPHÆUS WITH THE OCCIPITAL BONE

Membrana tectoria.

Two alar.

Ligamentum apicis dentis.

The *membrana tectoria* (occipito-axial ligament) (figs. 464, 465) is situated within the vertebral canal. It is a broad, strong band, which covers the dens and its ligaments, and appears to be a prolongation upwards of the posterior longitudinal ligament of the vertebral column. It is fixed, below, to the posterior surface of the body of the epistropheus, and, expanding as it ascends, is attached above to the basilar part of the occipital bone, in front of the foramen magnum, where it blends with the cranial dura mater.

The *alar ligaments* (fig. 464) are two strong, rounded cords, which arise one on either side of the upper part of the dens, and, passing obliquely upwards and lateralwards, are inserted into rough impressions on the medial sides of the condyles of the occipital bone. The alar ligaments limit rotation of the cranium and therefore receive the name of *check ligaments*. Between them is the *ligamentum apicis dentis* (fig. 465), which extends from the tip of the dens to the anterior margin of the foramen magnum, being intimately blended with the deep portion of the anterior atlanto-occipital membrane and with the superior crus of the transverse ligament of the atlas. It is regarded as a rudimentary intervertebral fibrocartilage, and traces of the notochord may persist in it.

In addition to the ligaments which unite the atlas and epistropheus to the skull, it must be remembered that the *ligamentum nuchæ* (p. 352) connects the cervical vertebræ with the cranium.

Applied Anatomy.—The ligaments of the vertebral column are so strong, and the bones so interlocked by the arrangement of their articulating processes, that dislocation is very uncommon, and, even in the upper part of the neck, rarely occurs unless accompanied by fracture. Dislocation of the occipital bone from the atlas has been recorded only in one or two cases, but dislocation of the atlas from the epistropheus, with rupture of the transverse ligament of the atlas, is much more common: it is the mode in which death is produced in many cases of execution by hanging. Below the third cervical vertebra, dislocation without fracture occasionally takes place.

COSTOVERTEBRAL ARTICULATIONS

The articulations of the ribs with the vertebral column may be divided into two sets, one connecting the heads of the ribs with the bodies of the vertebræ, another uniting the necks and tubercles of the ribs with the transverse processes.

1. ARTICULATIONS OF THE HEADS OF THE RIBS (fig. 466)

These consist of a series of arthrodia, and are sometimes named *costocentral joints*. They are formed by the articulation of the heads of the typical ribs with the foveæ on the contiguous margins of the bodies of the thoracic vertebræ and with the intervertebral fibrocartilages between them; the first, tenth, eleventh, and twelfth ribs each articulate with a single vertebra. The ligaments of the joints are:

The articular capsules.

Radiate.

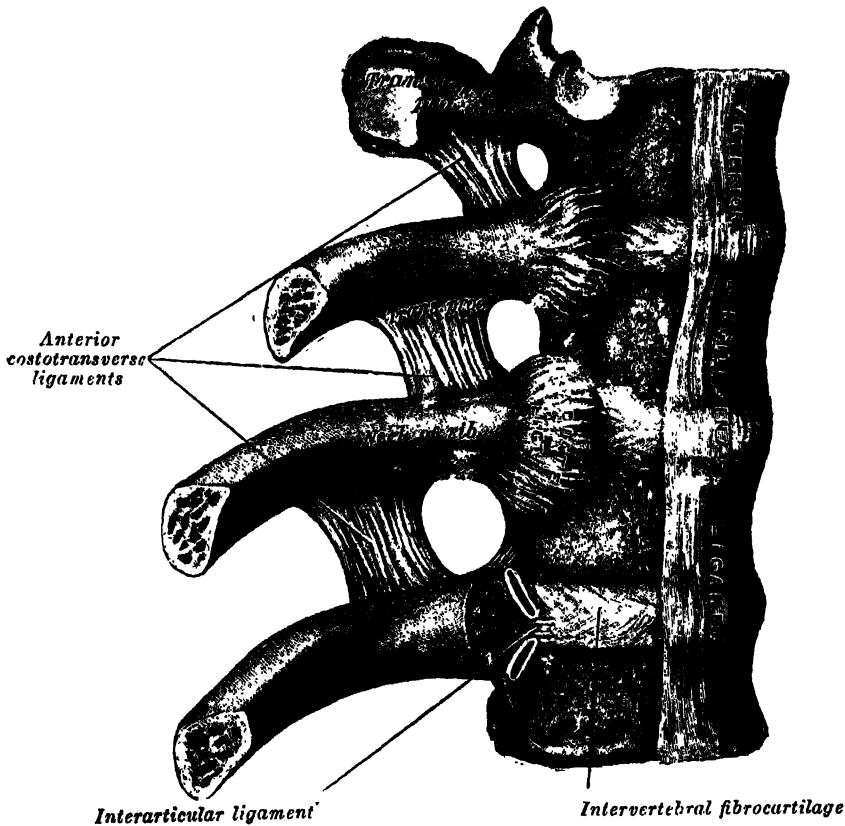
Interarticular.

In the majority of these articulations, viz. the second to the ninth inclusive, two articular capsules are present, since the joint is divided into two by an interarticular ligament. The articular capsules connect the heads of the ribs with the circumferences of the articular cavities formed by the intervertebral fibrocartilages and the adjacent vertebræ. Some of their upper fibres pass through the intervertebral foramen to the back of the intervertebral fibrocartilage, while the posterior fibres are continuous with the ligament of the neck of the rib.

The radiate ligament (stellate ligament) connects the anterior part of the head of each rib with the sides of the bodies of two vertebræ, and the intervertebral fibrocartilage between them. It is attached to the anterior part of the head of the rib, just beyond the articular surface. The superior fibres ascend and are connected with the body of the vertebra above; the inferior fibres descend to the body of the vertebra below; the middle fibres, the smallest and least distinct, are horizontal and attached to the intervertebral fibrocartilage.

In the case of the first rib, this ligament is attached to the body of the last cervical vertebra, as well as to that of the first thoracic. In the articulations of the heads of the tenth, eleventh, and twelfth ribs, each of which articulates with a single vertebra, the fibres of the ligament in each case are connected to the vertebra above, as well as to that with which the rib articulates.

FIG. 466.—Costovertebral articulations. Anterior view.



The interarticular ligament is situated in the interior of the joint. It consists of a short band of fibres, flattened from above downwards, attached laterally to the crest separating the two articular facets on the head of the rib, and medially to the intervertebral fibrocartilage; it divides the joint into two cavities and is covered on its upper and lower surfaces by the synovial strata of the articular capsules. In the joints of the first, tenth, eleventh, and twelfth ribs, the interarticular ligament does not exist; consequently, there is but one cavity in each of these articulations. This ligament is the homologue of the *ligamentum conjugale* present in some mammals, and uniting the heads of opposite ribs across the back of the intervertebral fibrocartilage.

2. COSTOTRANSVERSE ARTICULATIONS (fig. 467)

The articular portion of the tubercle of the rib forms with the articular surface on the adjacent transverse process an arthrodiar joint. In the eleventh and twelfth ribs this articulation is wanting.

The ligaments of the joint are :

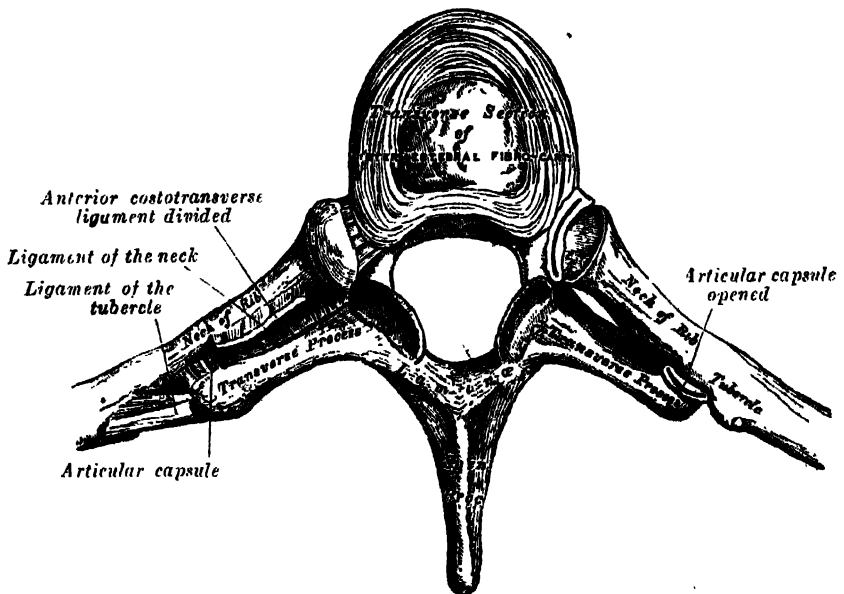
The articular capsule.
Anterior costotransverse.
Ligament of the tubercle of the rib.

Posterior costotransverse.
Ligament of the neck of the rib.
Ligament of the tubercle of the rib.

The ~~articular~~ capsule is a thin membrane attached to the circumference of the articular surfaces, and lined by a synovial stratum.

The anterior costotransverse ligament is attached below to the crest on the upper border of the neck of the rib, and passes obliquely upwards and lateralwards to the lower border of the transverse process immediately above. It is in relation, in front, with the intercostal vessels and nerve; its medial border is thickened and free, and forms the lateral boundary of an aperture

FIG. 467.—Costotransverse articulations. Seen from above.



which transmits the posterior branches of the intercostal vessels and the posterior division of the intercostal nerve; its lateral border is continuous with a thin aponeurosis which covers the *Intercostalis externus*.)

The first rib has no anterior costotransverse ligament. The neck of the twelfth rib is connected to the base of the transverse process of the first lumbar vertebra by a band of fibres, named the *lumbocostal ligament*; it is in series with the anterior costotransverse ligaments.

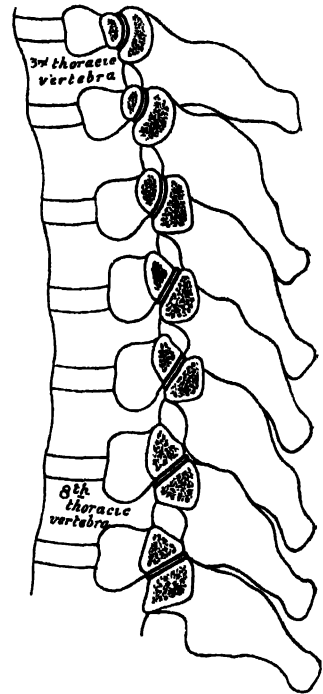
The posterior costotransverse ligament is a feeble band which is attached below to the neck of the rib, behind and medial to the anterior costotransverse ligament; it passes upwards and medialwards to the base of the transverse process and lateral border of the inferior articular process of the vertebra above.

The ligament of the neck of the rib (*interosseous costotransverse ligament*) consists of short but strong fibres, connecting the rough surface on the back of the neck of the rib with the anterior surface of the adjacent transverse process. A rudimentary ligament may be present in the case of the eleventh and twelfth ribs.

The ligament of the tubercle of the rib is a short but thick and strong fasciculus, which passes obliquely from the apex of the transverse process to the rough non-articular portion of the tubercle of the rib. The ligaments attached to the upper ribs ascend from the transverse processes; they are shorter and more oblique than those attached to the inferior ribs, which descend slightly.

Movements.—The heads of the ribs are so closely connected to the bodies of the vertebræ by the radiate and interarticular ligaments that only slight gliding movements of the articular surfaces on one another can take place. Similarly, the strong ligaments binding the necks and tubercles of the ribs to the transverse processes limit the movements of the costotransverse joints to slight gliding, the nature of which is determined by the shape and direction of the articular surfaces (fig. 468). On the upper six ribs the articular surfaces on the tubercles are oval in shape and convex from above downwards; they fit into corresponding concavities on the anterior surfaces of the transverse processes, so that upward and downward movements of the tubercles are associated with rotation of the rib-neck on its long axis. On the seventh, eighth, ninth, and tenth ribs the articular surfaces on the tubercles are flat, and are directed obliquely downwards, medialwards, and backwards. The surfaces with which they articulate are placed on the upper margins of the transverse processes; when, therefore, the tubercles are drawn up they are at the same time carried backwards and medialwards. The two joints, costocentral and costotransverse, move simultaneously and in the same directions, the total effect being that the neck of the rib moves as if on a single joint, of which the costocentral and costotransverse articulations form the ends. In the upper six ribs the neck of the rib moves but slightly upwards and downwards; its chief movement is one of rotation round its own long axis, rotation backwards being associated with depression, rotation forwards with elevation. In the seventh, eighth, ninth, and tenth ribs the neck of the rib moves upwards, backwards, and medialwards, or downwards, forwards, and lateralwards; very slight rotation accompanies these movements.

FIG. 468.—Section of the costotransverse joints from the third to the ninth inclusive. Contrast the concave facets on the upper with the flattened facets on the lower transverse processes.



STERNOCOSTAL ARTICULATIONS (fig. 469)

The cartilages of the true ribs, with the exception of the first, articulate with the sternum by arthrodial joints. The cartilage of the first rib is directly united with the sternum, and the joint between this rib and the sternum is a synchondrosis.

The ligaments of the arthrodial joints are :

The articular capsules.
Radiate sternocostal.

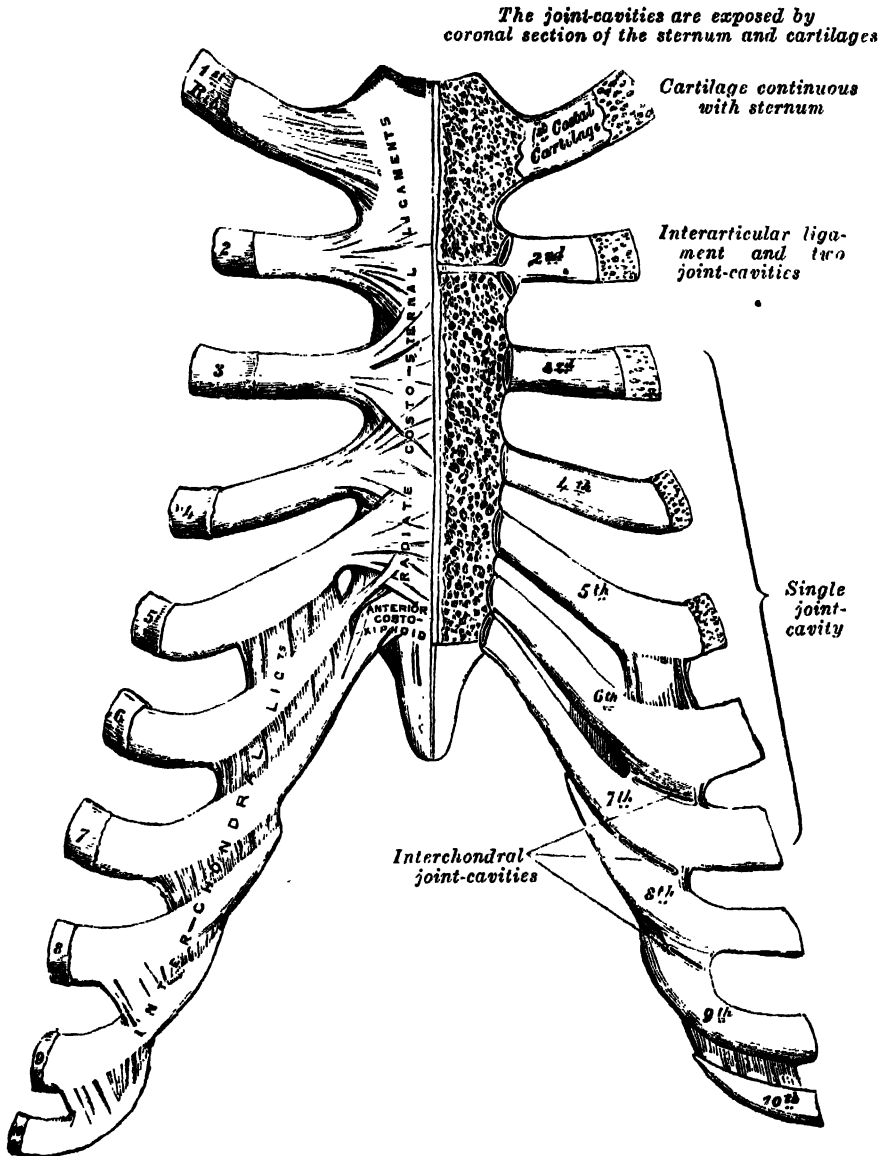
Interarticular sternocostal.
Costoxiphoid.

The **articular capsules** surround the joints between the sternum and the cartilages of the ribs from the second to the seventh inclusive. They are very thin, intimately blended with the radiate sternocostal ligaments, and strengthened at the upper and lower parts of the articulations by a few fibres, which connect the cartilages to the side of the sternum.

The **radiate sternocostal ligaments** are broad, thin membranous bands which radiate from the front and back of the sternal ends of the cartilages of the true ribs to the anterior and posterior surfaces of the sternum. Their superficial fibres intermingle with the fibres of the ligaments above and below them, with those of the opposite side, and on the front of the sternum with the tendinous fibres of origin of the Pectoralis major, forming a thick fibrous membrane (*membrana sterni*) which envelops the bone, and is more distinct at its lower than at its upper part.

The interarticular sternocostal ligaments are found constantly only between the second costal cartilages and the sternum. The cartilage of the *second rib* is connected with the sternum by means of an interarticular ligament, attached laterally to the cartilage of the rib, and medially to the fibrocartilage which unites the manubrium and body of the sternum. Occasionally the cartilage of the *third rib* is connected with the first and second pieces of the body

FIG. 469.—Sternocostal and interchondral articulations. Anterior view.



of the sternum by an interarticular ligament. Still more rarely, similar ligaments are found in the other four joints of the series. In the lower two an interarticular ligament sometimes obliterates the joint-cavity, so as to convert the articulation into an amphiarthrosis. After middle life the articular surfaces lose their polish, become roughened, and the synovial strata apparently disappear. In old age, the cartilages of most of the ribs become continuous with the sternum, and the joint-cavities are consequently obliterated.

The costoxiphoid ligaments connect the anterior and posterior surface of the seventh costal cartilage, and sometimes those of the sixth, to the front

and back of the xiphoid process. They vary in length and breadth in different subjects; those on the back of the joint are less distinct than those in front.

Movements.—Slight gliding movements are permitted in the sternocostal articulations.

INTERCHONDRAL ARTICULATIONS (fig. 469)

The contiguous borders of the sixth and seventh, the seventh and eighth, the eighth and ninth, and sometimes the ninth and tenth, costal cartilages articulate with each other by small smooth, oblong facets. Each articulation is enclosed in a thin *articular capsule*, lined by a synovial stratum and strengthened laterally and medially by *interchondral ligaments* which pass from one cartilage to the other. Sometimes the fifth costal cartilages, more rarely the ninth and tenth, articulate by their lower borders with the adjoining cartilages by small oval facets; more frequently the connexion is by a few ligamentous fibres.

COSTOCHONDRAL ARTICULATIONS

The lateral end of each costal cartilage is received into a depression in the sternal end of the rib, and the two are enveloped by the periosteum.

ARTICULATION OF THE MANUBRIUM WITH THE BODY OF THE STERNUM

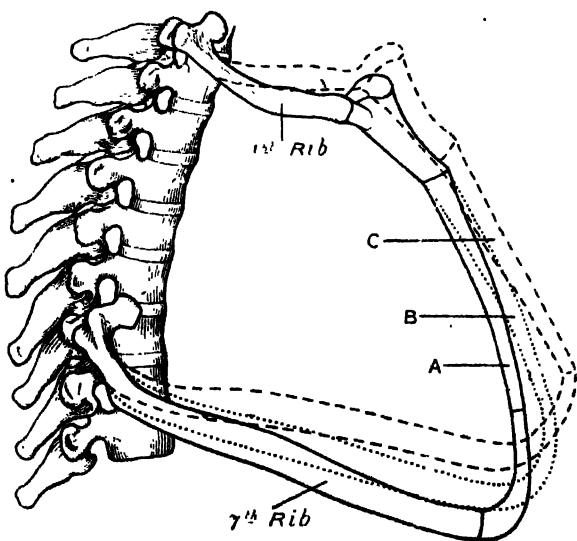
In the majority of cases the joint between the manubrium and the body of the sternum is a symphysis, the bony surfaces being coated with cartilage and connected by a disc of fibrocartilage which tends to ossify in advanced life. In rather more than thirty per cent. of cases the central part of the disc undergoes absorption and the joint is converted into a diarthrodial one. The two segments of the bone are also connected by the *membrana sterni*.

MECHANISM OF THE THORAX

Each rib possesses its own range and variety of movements, but the movements of all are combined in the respiratory excursions of the thorax. Each rib may be regarded as a lever, the fulcrum of which is situated immediately outside the costotransverse articulation, so that when the body of the rib is elevated the neck is depressed and *vice versa*; from the disproportion in length of the arms of the lever a slight movement at the vertebral end of the rib is greatly magnified at the anterior extremity.

The anterior ends of the ribs lie on a lower plane than the posterior; when therefore the body of the rib is elevated the anterior extremity is also thrust forwards. Again, the middle of the body of the rib lies in a plane below that passing through the two extremities, so that when the body is elevated relatively to its ends it is at

FIG. 470.—Lateral view of first and seventh ribs in position, showing the movements of the sternum and ribs in, A, ordinary expiration; B, quiet inspiration; C, deep inspiration.



the same time carried outwards from the median plane of the thorax; further, each rib forms the segment of a curve which is greater than that of the rib immediately

above. Therefore the elevation of a rib increases the transverse diameter of the thorax in the plane to which it is raised. The modifications of the rib movements at their vertebral ends have already been described (p. 361). Further modifications result from the attachments of their anterior extremities, and it is convenient therefore to consider separately the movements of the ribs of the three groups—vertebrosternal, vertebrochondral, and vertebral.

Vertebrosteral ribs (figs. 470, 471).—The first rib differs from the others of this group in that its attachment to the sternum is a rigid one; this is counterbalanced to some extent by the fact that its head possesses no interarticular ligament, and is therefore more movable. The first pair of ribs with the manubrium sterni move as a single piece, the anterior portion being elevated by rotatory movements at the vertebral extremities. In normal quiet respiration the movement of this arc is practically *nil*; when it does occur the anterior part is raised and carried forwards, increasing the anteroposterior and transverse diameters of this region of the chest.

FIG. 471.—Diagram showing the axes of movement (AB and CD) of a vertebrosteral rib. The interrupted lines indicate the position of the rib in inspiration.

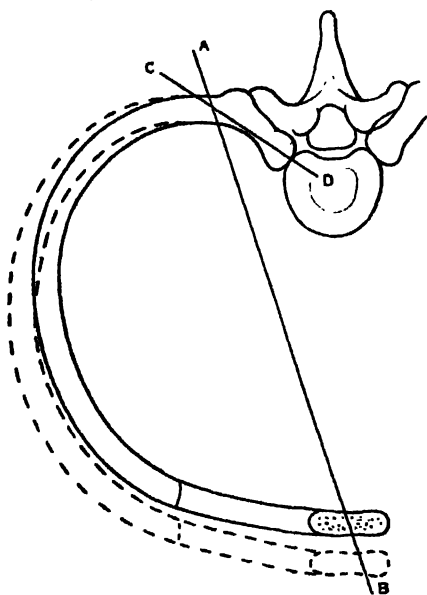
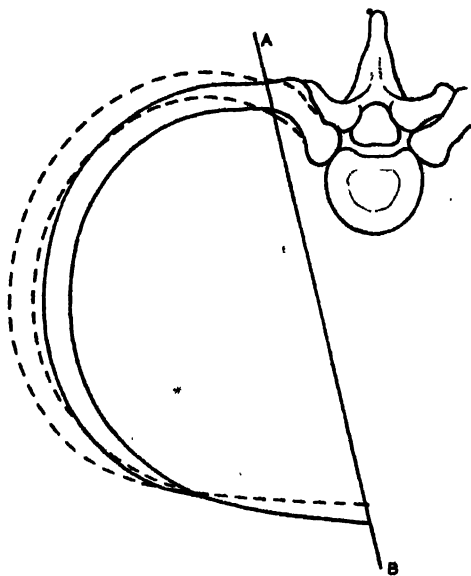


FIG. 472.—Diagram showing the axis of movement (AB) of a vertebrochondral rib. The interrupted lines indicate the position of the rib in inspiration.



The movement of the second rib is also slight in normal respiration, as its anterior extremity is fixed to the manubrium, and prevented therefore from moving upwards. The sternocostal articulation, however, allows the middle of the body of the rib to be drawn up, and in this way the transverse thoracic diameter is increased. Elevation of the third, fourth, fifth, and sixth ribs raises and thrusts forwards their anterior extremities, the greater part of the movement being effected by the rotation of the rib-neck backwards. The thrust of the anterior extremities carries forwards and upwards the body of the sternum, which moves on the joint between it and the manubrium, and thus the anteroposterior thoracic diameter is increased. This movement is, however, soon arrested, and the elevating force is then expended in raising the middle part of the body of the rib and everting its lower border; at the same time the costochondral angle is opened out. By these latter movements a considerable increase in the transverse diameter of the thorax is effected.

Vertebrochondral ribs (fig. 472).—The seventh rib is included with this group, as it conforms more closely to their type. While the movements of these ribs assist in enlarging the thorax for respiratory purposes, they are also concerned in increasing the upper abdominal space for viscera displaced by the action of the Diaphragm. The costal cartilages articulate with one another, so that each pushes up that above it, the final thrust being directed to pushing forwards and upwards the lower end

of the body of the sternum. The amount of elevation of the anterior extremities is limited on account of the very slight rotation of the rib-neck. Elevation of the shaft is accompanied by an outward and backward movement; the outward movement everts the anterior end of the rib and opens up the subcostal angle, while the backward movement pulls back the anterior extremity and counteracts the forward thrust due to its elevation; this latter is most noticeable in the lower ribs, which are the shortest. The total result is a considerable increase in the transverse and a diminution in the median anteroposterior diameter of the upper part of the abdomen; at the same time, however, the lateral anteroposterior diameters of the abdomen are increased.

Vertebral ribs.—Since these ribs have free anterior extremities and only costo-central articulations with no interarticular ligaments, they are capable of slight movements in all directions. When the other ribs are elevated these are depressed and fixed to form points of action for the Diaphragm.

ARTICULATIONS OF THE UPPER EXTREMITY

The articulations of the upper extremity comprise the following :

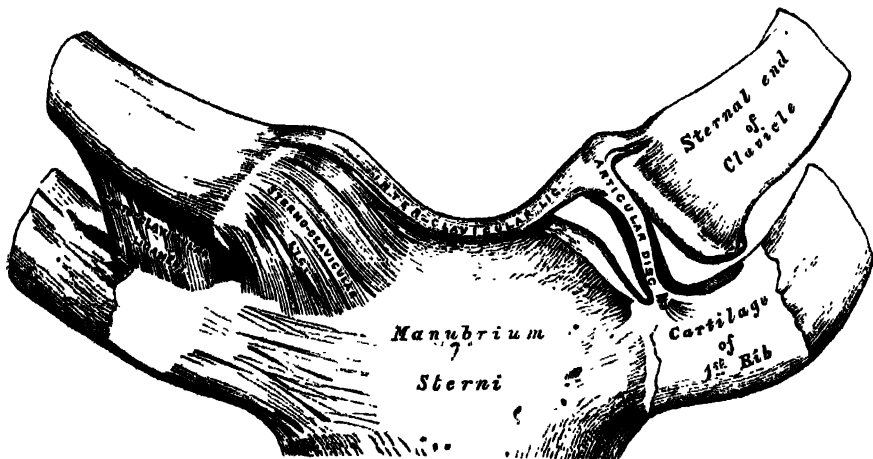
- | | |
|--------------------------|--------------------------|
| I. Sternoclavicular. | VI. Radiocarpal (wrist). |
| II. Acromioclavicular. | VII. Intercarpal. |
| III. Humeral (shoulder). | VIII. Carpometacarpal. |
| IV. Cubital (elbow). | IX. Intermetacarpal. |
| V. Radio-ulnar. | X. Metacarpophalangeal. |
| | XI. Digital. |



I. STERNOCLAVICULAR ARTICULATION (fig. 473)

The sternoclavicular articulation is a double arthrodial joint. The parts entering into its formation are the sternal end of the clavicle, the upper and lateral part of the manubrium sterni, and the cartilage of the first rib. The

FIG. 473.—Sternoclavicular articulation. Anterior view.



articular surface of the clavicle is much larger than that of the sternum, and is invested with a layer of cartilage,* which is considerably thicker than that on the latter bone. The ligaments of this joint are :

The articular capsule.
Sternoclavicular.

Interclavicular.
Costoclavicular.

The articular disc.

* According to Bruch, the sternal end of the clavicle is covered by a tissue which is fibrous rather than cartilaginous in structure.

The articular capsule surrounds the articulation; in front and behind it is of considerable thickness, but above, and especially below, it is thin and partakes more of the character of areolar than of true fibrous tissue.

The sternoclavicular ligament is a broad band, covering the anterior surface of the articulation; it is attached above to the upper and front part of the sternal end of the clavicle, and, passing obliquely downwards and medially, is attached below to the front of the upper part of the manubrium sterni.

The interclavicular ligament is a curved band, which varies considerably in size in different individuals; it is continuous above with the fascia colli (deep cervical fascia); it passes from the upper part of the sternal end of one clavicle to that of the other, and is also attached to the upper margin of the sternum.

The costoclavicular ligament (rhomboid ligament) is short, flat, strong, and rhomboid in form. Attached below to the upper surface of the cartilage of the first rib, it ascends backwards and lateralwards, and is fixed above to the costal tuberosity on the under surface of the clavicle.

The articular disc is flat and nearly circular, and is interposed between the articulating surfaces of the sternum and clavicle. It is attached, above to the upper and posterior border of the articular surface of the clavicle; below to the cartilage of the first rib, near its junction with the sternum; and by its circumference to the articular capsule. It is thicker at the circumference than at the centre, and divides the joint into two cavities; each of its surfaces is clothed by a synovial stratum.

The arteries supplying the joint are derived from the internal mammary and suprascapular arteries; the nerves, from the anterior supraclavicular nerves.

Movements.—This articulation admits of a limited amount of motion in nearly every direction—upwards, downwards, backwards, forwards, as well as circumduction.) When these movements take place in the joint, the clavicle in its motion carries the scapula with it, this bone gliding on the outer surface of the chest. (This joint therefore forms the centre from which all movements of the supporting arch of the shoulder originate, and is the only point of articulation of the shoulder girdle with the trunk.) (The movements attendant on elevation and depression of the shoulder take place between the clavicle and the articular disc.) When the shoulder is moved forwards and backwards, the clavicle, with the articular disc, rolls to and fro on the articular surface of the sternum. Elevation of the shoulder is limited principally by the costoclavicular ligament; depression, by the interclavicular ligament and articular disc. The muscles which *raise* the shoulder are the upper fibres of the Trapezius, the Levator scapulæ, and the clavicular head of the Sternocleidomastoideus, assisted to a certain extent by the Rhomboidei which pull the vertebral border of the scapula backwards and upwards and so raise the shoulder. *Depression* of the shoulder is principally effected by gravity, assisted by the Subclavius, Pectoralis minor, and lower fibres of the Trapezius. The shoulder is drawn *backwards* by the Rhomboidei and the middle and lower fibres of the Trapezius, and *forwards* by the Serratus anterior and Pectoralis minor.

Applied Anatomy.—The strength of this joint mainly depends upon its ligaments, and it is owing to these, and to the fact that the force of the blow is usually transmitted along the long axis of the clavicle, that dislocation rarely occurs, and that the bone is broken rather than displaced. When dislocation does occur, the course which the displaced bone takes depends more upon the direction in which the violence is applied than upon the anatomical construction of the joint; it may be either forwards, backwards or upwards. Should it be displaced backwards it may cause pressure on the trachea. The chief point worthy of note, as regards the construction of the joint, in connexion with dislocation, is the fact that, owing to the shape of the articular surfaces, and the strength of the joint mainly depending upon the ligaments, the displacement when reduced is very liable to recur, and hence it is extremely difficult to keep the end of the bone in its proper place.

ACROMIOCLAVICULAR ARTICULATION

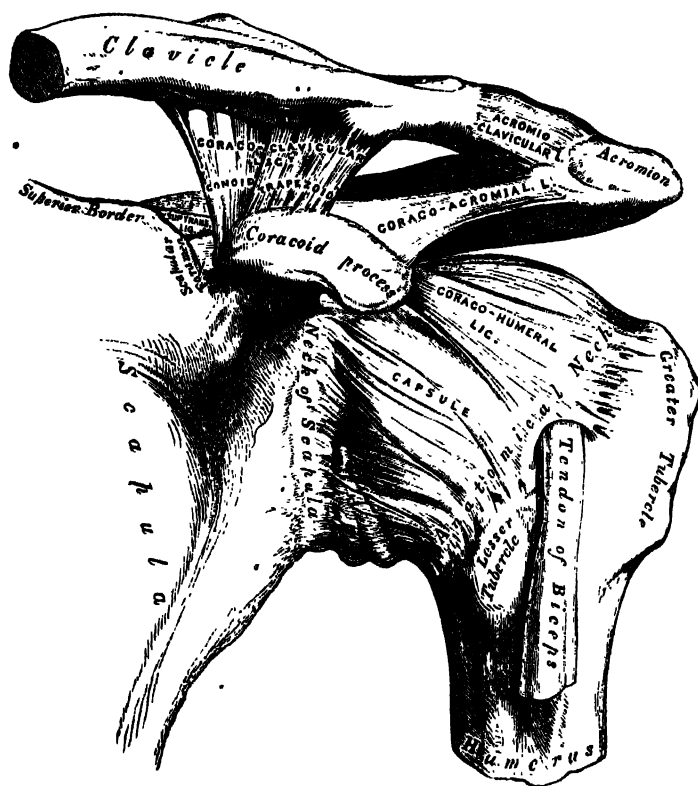
The acromioclavicular articulation (fig. 474) is an arthrodial joint between the acromial end of the clavicle and the medial margin of the acromion of the scapula. Its ligaments are :

The articular capsule.
Acromioclavicular.
The articular disc.

Coracoclavicular { Trapezoid
and
Conoid.

The articular capsule completely surrounds the articular margins, and is strengthened above by the acromioclavicular ligament.

FIG. 474.—The left shoulder-joint and acromioclavicular joint and the ligaments of the scapula.



The acromioclavicular ligament is a quadrilateral band, covering the superior part of the articulation, and extending between the upper part of the acromial end of the clavicle and the adjoining part of the upper surface of the acromion ; it is composed of parallel fibres, which interlace with the aponeuroses of the Trapezius and Deltoides.

The articular disc is frequently absent from this articulation. When present, it generally only partially separates the articular surfaces and occupies the upper part of the articulation. More rarely, it completely divides the joint into two cavities.

The coracoclavicular ligament (fig. 474) connects the clavicle with the coracoid process of the scapula. It does not properly belong to the acromioclavicular articulation, but is usually described with it since it forms a most efficient means of retaining the clavicle in contact with the acromion. It consists of two parts, viz. the trapezoid and conoid ligaments, which are usually separated by a bursa.

The trapezoid ligament, the anterior and lateral fasciculus, is broad, thin, and quadrilateral. It is attached, below, to the upper surface of the coracoid

process; above, to the oblique ridge on the under surface of the clavicle. Its anterior border is free, its posterior is joined with the conoid ligament, the two forming, by their junction, an angle projecting backwards.

The *conoid ligament*, the posterior and medial fasciculus, is a dense band of fibres, conical in form, with its base directed upwards. It is attached by its apex to a rough impression at the base of the coracoid process, medial to the trapezoid ligament; above, by its base, to the coracoid tuberosity on the under surface of the clavicle, and to a line proceeding medialwards from it for 1.25 cm.

The *arteries* supplying the joint are derived from the transverse scapular and thoraco-acromial arteries; the *nerves*, from the *suprascapular* and *axillary* nerves.

Movements.—The movements of this articulation are of two kinds: (1) a *gliding* motion of the articular end of the clavicle on the acromion; (2) *rotation* of the scapula forwards and backwards upon the clavicle. The extent of this rotation is limited by the two portions of the coracoclavicular ligament, the trapezoid limiting rotation forwards, and the conoid backwards.

The acromioclavicular joint has important functions in the movements of the upper extremity. Humphry pointed out * that if there had been no joint between the clavicle and scapula, the circular movement of the scapula on the ribs (as in throwing the shoulders backwards or forwards) would have been attended with a greater alteration in the direction of the shoulder than is consistent with the free use of the arm in such positions, and it would have been impossible to give a blow straight forwards with the full force of the arm: that is to say, with the combined force of the scapula, arm, and forearm. 'This joint,' as he happily says, 'is so adjusted as to enable either bone to turn in a hinge-like manner upon a vertical axis drawn through the other, and it permits the surfaces of the scapula, like the baskets in a roundabout swing, to look the same way in every position, or nearly so.' Again, when the whole arch formed by the clavicle and scapula rises and falls (in elevation or depression of the shoulder), the joint between these two bones enables the scapula still to maintain its lower part in contact with the ribs.

Applied Anatomy.—The acromioclavicular joint owes its security mainly to the coracoclavicular ligament, which limits the amount of movement of the acromial end of the clavicle either upwards, backwards, or forwards. Owing to the slanting shape of the articular surfaces of this joint, dislocation generally occurs upwards; that is to say, the acromial end of the clavicle is displaced above the acromion of the scapula. The displacement is often incomplete, on account of the strong coracoclavicular ligaments, which remain unturned. The same difficulty exists, as in the sternoclavicular dislocation, in maintaining the end of the bone in position after reduction.

LIGAMENTS OF THE SCAPULA

The ligaments of the scapula (fig. 474) are:

Coraco-acromial.

Superior and Inferior transverse.

The *coraco-acromial ligament* is a strong triangular band, extending between the coracoid process and the acromion. Its apex is attached to the summit of the acromion just in front of the articular surface for the clavicle; and its base to the whole length of the lateral border of the coracoid process. This ligament, together with the coracoid process and the acromion, forms a vault for the protection of the head of the humerus. It sometimes consists of two strong marginal bands and a thinner intervening portion, the two bands being attached respectively to the apex and the base of the coracoid process, and joining together at the acromion.

When the Pectoralis minor is inserted, as occasionally is the case, into the capsule of the shoulder-joint instead of into the coracoid process, it passes between these two bands, and the intervening portion of the ligament is then deficient.

The *superior transverse ligament* (*suprascapular ligament*) converts the scapular notch into a foramen, and is sometimes ossified. It is a thin and flat fasciculus, narrower at the middle than at the extremities, which are attached

* *A Treatise on the Human Skeleton.*

to the base of the coracoid process and the medial end of the scapular notch respectively. The suprascapular nerve runs through the foramen; the transverse scapular vessels cross over the ligament.

The **inferior transverse ligament** (spinoglenoid ligament) is a weak membranous band, situated behind the neck of the scapula and stretching from the lateral border of the spine of the scapula to the margin of the glenoid cavity. It forms an arch under which the transverse scapular vessels and suprascapular nerve enter the infraspinatus fossa. It is frequently absent.

III. HUMERAL ARTICULATION OR SHOULDER-JOINT

The shoulder-joint (fig. 474) is an enarthrodial or ball-and-socket joint. The bones entering into its formation are the hemispherical head of the humerus and the shallow glenoid cavity of the scapula, an arrangement which permits of very considerable movement, while the joint itself is protected against displacement, by the muscles which surround it. The joint is also protected above by an arch, formed by the coracoid process, the acromion, and the coraco-acromial ligament. The articular cartilage on the head of the humerus is thicker at the centre than at the circumference, the reverse being the case with the articular cartilage of the glenoid cavity. The ligaments of the articulation are :

The articular capsule.
Coracohumeral.

The glenoidal labrum.
Transverse humeral.

The **articular capsule** (fig. 475) envelops the joint, and is attached, above, to the circumference of the glenoid cavity beyond the glenoidal labrum; below, to the anatomical neck of the humerus, approaching nearer to the articular cartilage at the upper than at the lower part of the neck. It is thicker above and below than elsewhere, and is so remarkably loose and lax, that the bones may be separated from each other for a distance of about 2.5 cm., an evident provision for the great freedom of movement which is permitted at this articulation. It is strengthened, above, by the Supraspinatus; below, by the long head of the Triceps brachii; behind, by the tendons of the Infraspinatus and Teres minor; and in front, by the tendon of the Subscapularis. There are usually three openings in the capsule. One anteriorly, below the coracoid process, establishes a communication between the joint and a bursa beneath the tendon of the Subscapularis; another, between the tubercles of the humerus, gives passage to the long tendon of the Biceps brachii; the third, which is not constant, is at the posterior part, between the joint and a bursal sac under the tendon of the Infraspinatus.

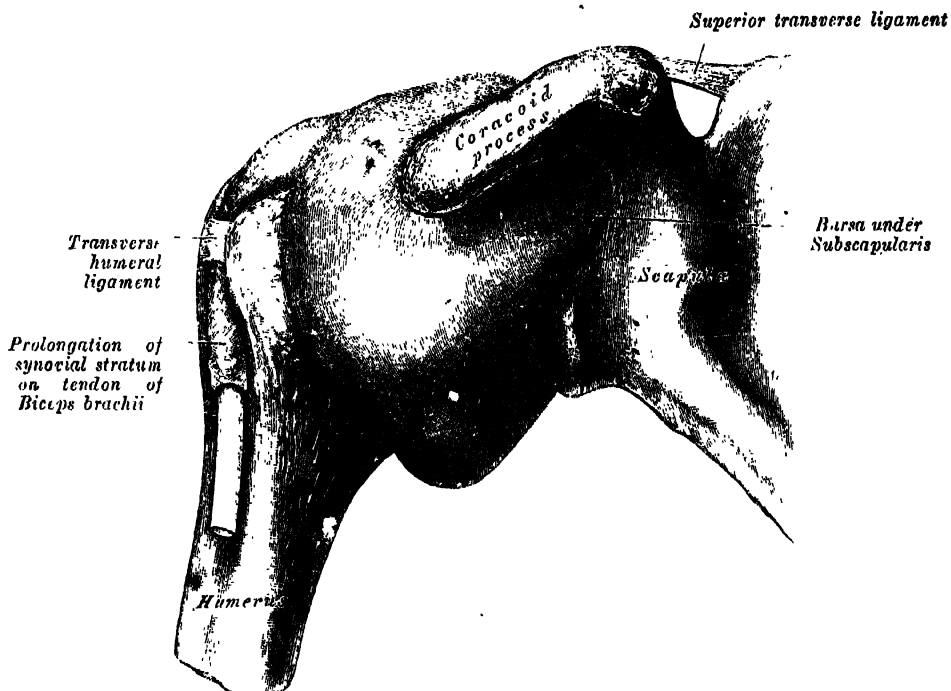
Three supplemental bands, which are named the *glenohumeral ligaments*, strengthen the capsule. These are best seen by opening the posterior part of the capsule of the joint and removing the head of the humerus. One on the medial side of the joint passes from the medial edge of the glenoid cavity to the lower part of the lesser tubercle of the humerus; a second at the lower part of the joint extends from the under edge of the glenoid cavity to the under part of the anatomical neck; a third at the upper part of the joint is fixed above to the apex of the glenoid cavity close to the root of the coracoid process, and passing downwards along the medial edge of the tendon of the Biceps brachii, is attached below to a small depression above the lesser tubercle. In addition to these, the capsule is strengthened in front by two bands, one derived from the tendon of the Pectoralis major, the other from the tendon of the Teres major.

The **synovial stratum** is reflected from the margin of the glenoid cavity over the labrum; it is then reflected over the inner surface of the capsule, and covers the lower part and sides of the anatomical neck of the humerus as far as the articular cartilage on the head of the bone. The tendon of the long head of the Biceps brachii passes through the fibrous stratum of the capsule and is enclosed in a tubular sheath of the synovial stratum, which is reflected upon it from the summit of the glenoid cavity and is continued round the tendon into the intertubercular sulcus as far as the surgical neck of the humerus (fig. 476).

The **coracohumeral ligament** is a broad band which strengthens the upper part of the capsule. It arises from the lateral border of the root of the coracoid process, and passes obliquely downwards and lateralwards to the front of the greater tubercle of the humerus, blending with the tendon of the Supraspinatus. The hinder and lower border of the ligament is united to the capsule; its anterior and upper border is free, and overlaps the capsule.

The **transverse humeral ligament** (fig. 475) is a broad band passing from the lesser to the greater tubercle of the humerus; it converts the intertubercular sulcus into a canal, and its attachment is always limited to that portion of the bone which lies above the epiphysial line.

FIG. 475.—Articular capsule of shoulder-joint (distended). Anterior aspect.



The **glenoidal labrum** (glenoid ligament) is a fibrocartilaginous rim attached round the margin of the glenoid cavity. It is triangular on section, the base being fixed to the circumference of the cavity, while the free edge is thin and sharp. It is continuous above with the tendon of the long head of the Biceps brachii, which gives off two fasciculi to blend with the fibrous tissue of the labrum. It deepens the articular cavity, and protects the edges of the bone.

Bursæ.—The bursæ in the neighbourhood of the shoulder-joint are the following: (1) One is constantly found between the tendon of the Subscapularis muscle and the capsule: it communicates with the synovial cavity through an opening in the front of the capsule; (2) one is sometimes found between the tendon of the Infraspinatus and the capsule; it occasionally opens into the joint; (3) a large one exists between the under surface of the Deltoides and the capsule, but does not communicate with the joint: this bursa is prolonged under the acromion and coraco-acromial ligament, and intervenes between these structures and the capsule; (4) a large one is situated on the summit of the acromion; (5) one is frequently found between the coracoid process and the capsule; (6) one exists beneath the Coracobrachialis; (7) one lies between the Teres major and the long head of the Triceps brachii; (8) one is placed in front of, and another behind, the tendon of the Latissimus dorsi.

The **muscles** in relation with the joint are, above, the Supraspinatus; below, the long head of the Triceps brachii; in front, the Subscapularis; behind, the

Infraspinatus and Teres minor; within, the tendon of the long head of the Biceps brachii. The Deltoideus covers the articulation in front, behind, and laterally.

The *arteries* supplying the joint are derived from the anterior and posterior humeral circumflex, and transverse scapular arteries; the *nerves*, from the axillary and suprascapular nerves.

Movements.—The shoulder-joint is capable of flexion, extension, abduction, adduction, circumduction, and rotation. The humerus is *flexed* (drawn forwards) by the Pectoralis major, anterior fibres of the Deltoideus, Coracobrachialis, and when the forearm is flexed, by the Biceps brachii; *extended* (drawn backwards) by the Latissimus dorsi, Teres major, posterior fibres of the Deltoideus, and, when the forearm is extended, by the Triceps brachii; it is *abducted* by the Deltoideus and Supraspinatus; it is *adducted* by the Subscapularis, Pectoralis major, Latissimus dorsi, and Teres major, and by the weight of the limb; it is *rotated outwards* by the Infraspinatus and Teres minor; and it is *rotated inwards* by the Subscapularis, Latissimus dorsi, Teres major, Pectoralis major, and the anterior fibres of the Deltoideus.

The most striking peculiarities in this joint are: 1. The large size of the head of the humerus in comparison with the depth of the glenoid cavity, even though this latter is supplemented by the glenoidal labrum. 2. The looseness of the capsule of the joint. 3. The intimate connexion of the capsule with the muscles attached to the head of the humerus. 4. The peculiar relation of the tendon of the long head of the Biceps brachii to the joint.

It is in consequence of the relative sizes of the two articular surfaces, and the looseness of the articular capsule, that the joint enjoys such free movement in all directions. When these movements of the arm are arrested in the shoulder-joint by the contact of the bony surfaces, and by the tension of the fibres of the capsule together with that of the muscles acting as accessory ligaments, the arm can be carried considerably farther by the movements of the scapula, involving, of course, motion at the sternoclavicular and acromioclavicular joints. These joints are therefore to be regarded as accessory to the shoulder-joint (see pp. 365 to 368). The extent of the scapular movements is very considerable, especially in extreme elevation of the arm, a movement best accomplished when the arm is thrown somewhat forwards and outwards, because the margin of the head of the humerus is by no means a true circle; the greatest diameter of the head is from the intertubercular groove, downwards, medialwards, and backwards, and the greatest elevation of the arm can be obtained by rolling its articular surface in the direction of this measurement.

The looseness of the capsule is so great that the arm will fall about 2.5 cm. from the scapula when the muscles are dissected from the capsule, and an opening made in it to counteract the atmospheric pressure. The movements of the joint, therefore, are not regulated by the capsule so much as by the surrounding muscles, an arrangement which 'renders the movements of the joint much more easy than they would otherwise have been, and permits a swinging, pendulum-like vibration of the limb when the muscles are at rest' (Humphry). The fact, also, that in all ordinary positions of the joint the capsule is not put on the stretch, enables the arm to move freely in all directions. Some movements are checked by the tension of appropriate portions of the capsule, as well as by the interlocking of the bones. Thus it is said that 'abduction is checked by the contact of the great tuberosity with the upper edge of the glenoid cavity; adduction by the tension of the coracohumeral ligament' (Beaunis and Bouchard). Cleland* maintains that the limitations of movement at the shoulder-joint are due to the structure of the joint itself, the glenoidal labrum fitting, in different positions of the elevated arm, into the anatomical neck of the humerus.

The scapula is capable of being moved upwards and downwards, and forwards and backwards, and, by a combination of these movements, circumducted on the wall of the chest. The muscles which *raise* the scapula are the upper fibres of the Trapezius, the Levator scapulæ, and the Rhomboidei; those which *depress* it are the lower fibres of the Trapezius, the Pectoralis minor, and, through the clavicle, the Subclavius. The scapula is drawn *backwards* by the Rhomboidei and the middle and lower fibres of the Trapezius, and *forwards* by the Serratus anterior and Pectoralis minor, assisted, when the arm is fixed, by the Pectoralis major. The mobility of the scapula is very considerable, and greatly assists the movements of

* *Journal of Anatomy and Physiology*, vol. i., 1867.

the arm at the shoulder-joint. Thus, in raising the arm from the side, the Deltoides and Supraspinatus can only lift it to a right angle with the trunk, the farther elevation of the limb being effected by the Trapezius and Serratus anterior moving the scapula on the wall of the chest. This mobility is of special importance in ankylosis of the shoulder-joint, the movements of the scapula compensating to a very great extent for the immobility of the joint.

Cathcart* has pointed out that in abducting the arm and raising it above the head, the scapula rotates throughout the whole movement with the exception of a short space at the beginning and at the end; that the humerus moves on the scapula not only while passing from the hanging to the horizontal position, but also in travelling upwards as it approaches the vertical above; that the clavicle moves not only during the second half of the movement but in the first as well, though to a less extent—i.e. the scapula and clavicle are concerned in the first stage as well as in the second; and that the humerus is partly involved in the second as well as chiefly in the first.

The peculiar relations of the tendon of the long head of the Biceps brachii to the shoulder-joint appear to subserve various purposes. In the first place, by its connexion with both the shoulder and elbow the muscle harmonises the action of the two joints, and acts as an elastic ligament in all positions, in the manner previously discussed (see p. 345). It strengthens the upper part of the articular cavity, and prevents the head of the humerus from being pressed up against the acromion when the Deltoides contracts; it thus fixes the head of the humerus as the centre of motion in the glenoid cavity. By its passage along the intertubercular sulcus it assists in steadying the head of the humerus in the various movements of the arm. When the arm is raised from the side the Biceps brachii assists the Supraspinatus and Infraspinatus in rotating the head of the humerus in the glenoid cavity. It also holds the head of the bone firmly in contact with the glenoid cavity, and prevents it slipping over the lower edge, or being displaced by the action of the Latissimus dorsi and Pectoralis major, as in climbing and many other movements.

Applied Anatomy.—Owing to the construction of the shoulder-joint and the freedom of movement which it enjoys, as well as in consequence of its exposed situation, it is more frequently dislocated than any other joint. Dislocation occurs when the arm is abducted, and when, therefore, the head of the humerus presses against the lower and front part of the capsule, which is the thinnest and least supported part of the ligament. The rent in the capsule almost invariably takes place in this situation, and through it the head of the bone escapes, so that the dislocation in most instances is primarily subglenoid. The head of the bone does not usually remain in this situation, between the tendons of the Subscapularis and the Triceps brachii, but generally assumes some other position; which varies according to the direction and amount of force producing the dislocation and the relative strength of the muscles in front of and behind the joint. As the muscles at the back are stronger than those in front, and especially since the long head of the Triceps brachii prevents the bone from passing backwards, dislocation forwards is much the more common. The most frequent position which the head of the humerus ultimately assumes is on the front of the neck of the scapula, beneath the coracoid process, and hence named subcoracoid. Occasionally, in consequence of a greater amount of force being brought to bear on the limb, the head is driven farther medialwards, and rests on the upper part of the front of the chest, beneath the clavicle (subclavicular). Sometimes it remains in the position in which it was primarily displaced, resting on the axillary border of the scapula (subglenoid), and rarely it passes backwards and remains in the infraspinatus fossa, beneath the spine (subspinous).

The shoulder-joint may be the seat of any of those inflammatory affections, either acute or chronic, which attack joints, though perhaps less frequently than some other articulations of equal size and importance. Acute synovitis may result from injury, rheumatism, or pyæmia, or may follow secondarily on acute epiphysitis in infants. It is attended with effusion into the joint, and when this occurs the capsule is evenly distended, and the contour of the joint rounded. Special projections may occur at the sites of the openings in the capsule. Thus a swelling may appear just medial to the lesser tubercle, from effusion into the bursa beneath the Subscapularis; or, again, a swelling which is sometimes bilobed may be seen in the interval between the Deltoides and Pectoralis major, from effusion into the diverticulum which runs down the intertubercular groove with the tendon of the Biceps brachii. The effusion into the joint-cavity can be best ascertained by examination from the axilla, where a soft, elastic, fluctuating swelling can usually be felt. In cases of septic synovitis, where incision is required, the opening should be made in front, over the most prominent point of the swelling. After the

* *Journal of Anatomy and Physiology*, 1884, vol. xviii.

pus has been evacuated a counter-opening should be made behind, so as to ensure efficient drainage.

Tuberculous arthritis not infrequently attacks the shoulder-joint, and may lead to total destruction of the articulation, when ankylosis may result, or long-protracted suppuration may necessitate excision. This joint is also one of those which is most liable to be the seat of osteo-arthritis, and may also be affected in gout and rheumatism; or in locomotor ataxy, when it becomes the seat of Charcot's disease.

Ankylosis is occasionally met with in the shoulder-joint as the result of destructive changes. The ankylosis usually takes place with the arm in a dependent position, and any attempt to raise the arm is attended by a rotation of the scapula on the wall of the chest.

Excision of the shoulder-joint may be required in cases of arthritis (especially the tuberculous form) which have gone on to destruction of the articulation; in compound dislocations and fractures, particularly those arising from gunshot injuries, in which there has been extensive injury to the head of the bone; in some cases of old unreduced dislocation, where there is much pain. The operation is best performed by making an incision from the middle of the coraco-acromial ligament down the arm for about 7 or 8 cm.; this will expose the intertubercular groove containing the tendon of the Biceps brachii, which should be hooked out of the way. The capsule is freely opened, and the muscles attached to the greater and lesser tubercles of the humerus are stripped off with the capsule, without dividing their attachments to the latter. The head of the bone can then be thrust out of the wound and sawn off; or divided with a narrow saw *in situ* and subsequently removed. The section should be made, if possible, just below the articular surface, so as to leave the bone as long as possible.

IV. CUBITAL ARTICULATION OR ELBOW-JOINT

The elbow-joint (figs. 478, 479) includes three articulations:—(1) *humero-ulnar*, between the trochlea of the humerus and the semilunar notch of the ulna, (2) *humero-radial*, between the capitulum of the humerus and the fovea on the head of the radius, and (3) *proximal radio-ulnar*, where the circumference of the radial head is retained in the circle formed by the annular ligament and the radial notch of the ulna (see p. 376). All three are included in a common articular capsule.

The humero-ulnar and humero-radial articulations together form a ginglymus or hinge-joint, the ligaments of which are:

The articular capsule.

Ulnar collateral.

Radial collateral.

Articular capsule.—The anterior part of the articular capsule is a broad and thin fibrous layer. It is attached, above, to the front of the medial epicondyle and to the front of the humerus immediately above the coronoid and radial fossæ; below, to the anterior surface of the coronoid process of the ulna and to the annular ligament (p. 376), being continuous on either side with the collateral ligaments. Its superficial fibres pass obliquely from the medial epicondyle of the humerus to the annular ligament. The middle fibres, vertical in direction, pass from the upper part of the coronoid depression and become partly blended with the preceding, but are inserted mainly into the anterior surface of the coronoid process. The deep or transverse set intersects these at right angles. It is in relation, in front, with the Brachialis, except at its most lateral part.

The posterior part of the articular capsule is thin and membranous, and consists of transverse and oblique fibres. Above, it is attached to the humerus immediately behind the capitulum and close to the medial margin of the trochlea, to the margins of the olecranon fossa, and to the back of the lateral epicondyle some little distance from the trochlea. Below, it is fixed to the upper and lateral margins of the olecranon, to the posterior part of the annular ligament, and to the ulna behind the radial notch. The transverse fibres form a strong fasciculus which bridges the olecranon fossa; under cover of this band a pouch of the synovial stratum and a pad of fat are displaced into the upper part of the fossa when the joint is extended. In the fat are a few scattered fibrous bundles which pass from the deep surface of the transverse band to the upper part of the fossa. It is in relation, behind, with the tendon of the Triceps brachii and the Anconæus.

The *synovial stratum* (figs. 476, 477) is very extensive. It extends from the margin of the articular surface of the humerus, and lines the coronoid,

radial and olecranon fossæ on that bone ; it is reflected over the deep surface of the capsule and lines the deep surface of the annular ligament. Projecting into the joint-cavity between the radius and ulna is a crescentic fold of the synovial stratum, suggesting the division of the joint into two : one the humero-radial, the other the humero-ulnar.

Between the fibrous and the synovial strata of the articular capsule are three masses of fat. The largest, over the olecranon fossa, is pressed into the fossa by the *Triceps brachii* during flexion ; the second, over the coronoid fossa, and the third, over the radial fossa, are pressed by the *Brachialis* into their respective fossæ during extension.

FIG. 476.—Articular capsule of elbow-joint (distended). Anterior aspect.



FIG. 477.—Articular capsule of elbow-joint (distended). Posterior aspect.



The ulnar collateral ligament (internal lateral ligament) (fig. 478) is a thick triangular band consisting of two portions, an anterior and a posterior, united by a thinner intermediate portion. The *anterior portion*, directed obliquely forwards, is attached, above, by its apex, to the front part of the medial epicondyle of the humerus ; and, below, by its broad base, to the medial margin of the coronoid process. The *posterior portion*, also of triangular form, is attached, above, by its apex, to the lower and back part of the medial epicondyle ; below, to the medial margin of the olecranon. Between these two bands a few intermediate fibres descend from the medial epicondyle to an *oblique band* which stretches between the olecranon and coronoid processes and converts the depression on the medial margin of the semilunar notch into a foramen, through which the intra-articular pad of fat is continuous with the extra-articular fat on the medial side of the joint. The ulnar collateral

FIG. 478.—Left elbow-joint, from medial side.

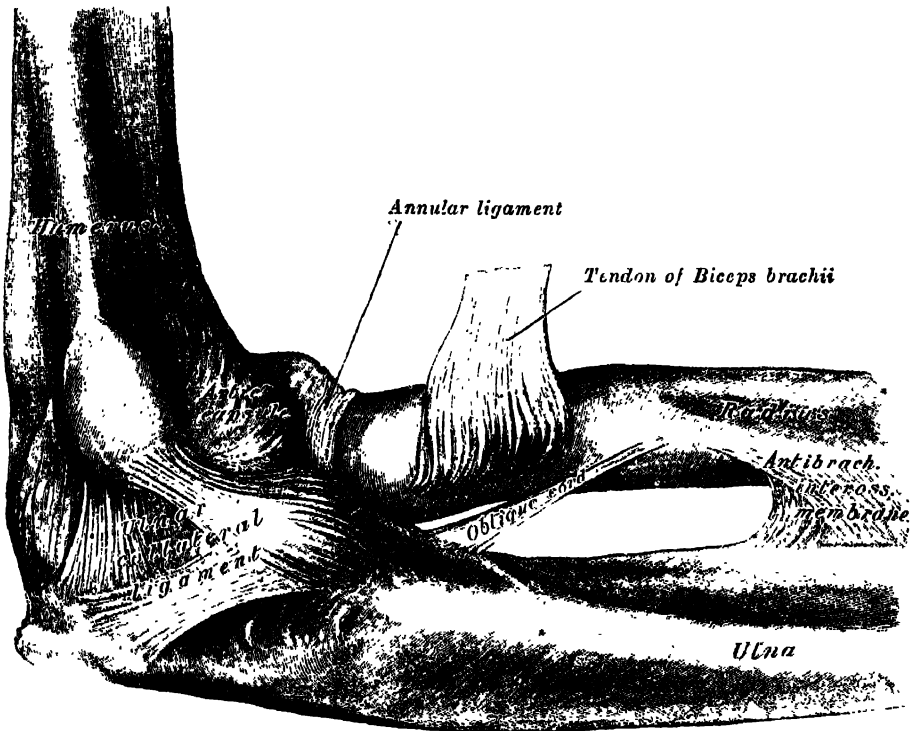
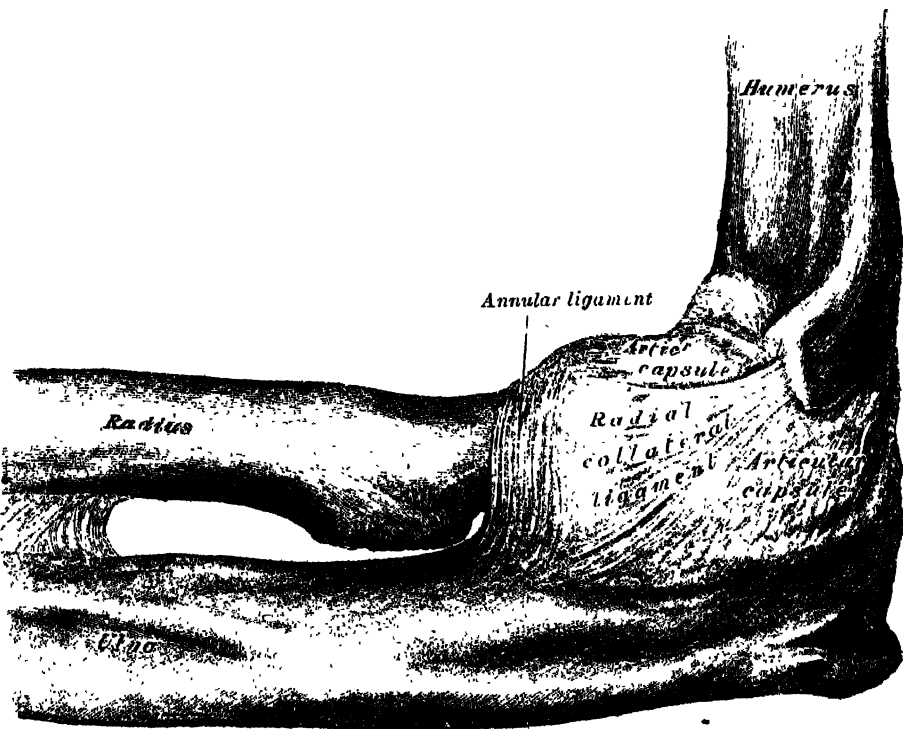


FIG. 479.—Left elbow-joint, from lateral side.



ligament is in relation with the *Triceps brachii* and *Flexor carpi ulnaris* and the ulnar nerve, and gives origin to part of the *Flexor digitorum sublimis*.

The **radial collateral ligament** (external lateral ligament) (fig. 479), a short and narrow fibrous band, less distinct than the ulnar collateral, is attached, above, to a depression below the lateral epicondyle of the humerus, and below, to the annular ligament; some of its most posterior fibres pass over that ligament, to be inserted into the lateral margin of the ulna. It is intimately blended with the origins of the *Supinator* and *Extensor carpi radialis brevis*.

The *muscles* in relation with the joint are, in front, the *Brachialis*; behind, the *Triceps brachii* and *Anconæus*; laterally, the *Supinator*, and the common tendon of origin of the extensor muscles; medially, the common tendon of origin of the flexor muscles, and the *Flexor carpi ulnaris*.

The *arteries* supplying the joint are derived from the anastomosis between the *profunda* and the superior and inferior ulnar collateral branches of the brachial, with the anterior, posterior, and interosseous recurrent branches of the ulnar, and the recurrent branch of the radial. These vessels form an anastomotic network around the joint.

The *nerves* of the joint are a twig from the ulnar, as it passes between the medial condyle and the olecranon; a filament from the musculocutaneous, and two from the median.

The movements at the elbow-joint are described on p. 378.

V. RADIO-ULNAR ARTICULATIONS

The articulation of the radius with the ulna is effected by ligaments which connect together the extremities and also the bodies of these bones. The ligaments may, consequently, be subdivided into three sets: 1, those of the proximal radio ulnar articulation; 2, the middle radio-ulnar ligaments; 3, those of the distal radio-ulnar articulation.

1. PROXIMAL RADIO-ULNAR ARTICULATION

This articulation forms a trochoid or pivot-joint between the circumference of the head of the radius and the ring formed by the radial notch of the ulna and the annular ligament.

The **annular ligament** (orbicular ligament) (figs. 476, 477, 480) is a strong band of fibres, which encircles the head of the radius, and retains it in contact with the radial notch of the ulna. It forms about four-fifths of the osseofibrous ring and is attached to the anterior and posterior margins of the radial notch; a few of its lower fibres are continued round below the notch and form at this level a complete fibrous ring. Its upper border blends with the anterior and posterior parts of the articular capsule of the elbow-joint, while from its lower border a thin loose membrane passes to be attached to the neck of the radius. A thickened band which extends from the inferior border of the annular ligament below the radial notch to the neck of the radius is known as the *quadrate ligament*. The *superficial surface* of the annular ligament is strengthened by the radial collateral ligament of the elbow, and affords origin to part of the *Supinator*. Its *deep surface* is lined by a synovial stratum which is continuous with that of the elbow-joint.

Movements.—The movements allowed in this articulation are limited to rotatory movements of the head of the radius within the ring formed by the annular ligament and the radial notch of the ulna; rotation forwards being called *pronation*; rotation backwards, *supination*. Pronation is performed by the *Pronator teres* and *Pronator quadratus*; supination by the *Biceps brachii* and *Supinator*, assisted to a slight extent by the *Extensor* muscles of the thumb.

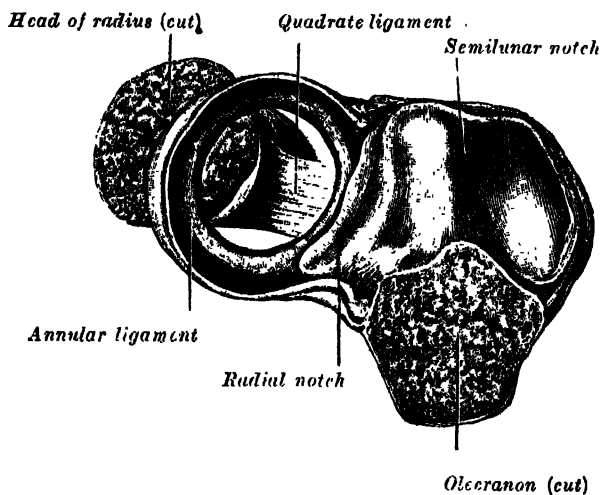
2. MIDDLE RADIO-ULNAR UNION

The bodies of the radius and ulna are connected by the oblique cord and the antibrachial interosseous membrane.

The **oblique cord** (fig. 478) is a small, flattened band, extending from the lateral side of the tubercle of the ulna at the base of the coronoid process to the radius a little below the radial tuberosity. Its fibres run in the opposite direction to those of the interosseous membrane. It is sometimes wanting.

The **antibrachial interosseous membrane** is a broad and thin sheet of fibrous tissue, the fibres of which slant obliquely downwards and medialwards, from the interosseous crest of the radius to that of the ulna; the lower part of the membrane is attached to the posterior of the two lines into which the interosseous crest of the radius divides. Two or three fibrous bands are occasionally found on the dorsal surface of this membrane; they descend obliquely from the ulna towards the radius, i.e. in a direction contrary to that of the other fibres. It is deficient above, commencing about 2.5 cm. below

FIG. 480.—Annular ligament of radius, from above. The head of the radius has been sawn off and the bone dislodged from the ligament.



the tuberosity of the radius; is broader in the middle than at either end; and presents an oval aperture a little above its lower margin, for the passage of the volar interosseous vessels to the back of the forearm. Between its upper border and the oblique cord is a gap, through which the dorsal interosseous vessels pass. This membrane serves to connect the bones, and to increase the extent of surface for the attachment of the deep muscles. It also transmits to the ulna and thence to the humerus any force acting upwards through the hand and radius. It is relaxed in complete pronation or supination, and is most tense when the hand is midway between the prone and supine positions. The membrane is in relation, *in front*, by its upper three-fourths, with the Flexor pollicis longus on the radial side, and with the Flexor digitorum profundus on the ulnar side; between these muscles are the volar interosseous vessels and nerve; by its lower fourth with the Pronator quadratus; *behind*, with the Supinator, Abductor pollicis longus, Extensor pollicis brevis, Extensor pollicis longus, Extensor indicis proprius; and, near the wrist, with the volar interosseous artery and dorsal interosseous nerve.

3. DISTAL RADIO-ULNAR ARTICULATION

This is a pivot-joint formed between the head of the ulna and the ulnar notch of the lower end of the radius; the surfaces are enclosed in an articular capsule and held together by an articular disc.

The **articular capsule** is slightly thickened in front and behind; above, it is lax and, with the synovial stratum, projects upwards as a pouch (*recessus sacciformis*) between the radius and the ulna.

The **articular disc** (fig. 483) is triangular in shape, and is placed distally to the head of the ulna, binding the lower ends of the ulna and radius firmly together. Its periphery is thicker than its centre, which is occasionally perforated. It is attached by its apex to a depression between the styloid process and the head of the ulna; and by its base, which is thin, to the prominent edge of the radius which separates the ulnar notch from the carpal articular surface. Its margins are united to the ligaments of the wrist-joint. Its *proximal surface*, smooth and concave, articulates with the head of the ulna, forming an arthrodial joint; its *distal surface*, also concave and smooth, forms part of the radiocarpal joint and articulates with the triquetral bone and medial part of the lunate bone. Each of its surfaces is clothed by a synovial stratum: the proximal, by that of the distal radio-ulnar articulation; the distal, by that of the radiocarpal joint.

Movements.—The movements of the three joints within the elbow should be studied together. The combination of the movements of flexion and extension of the forearm with those of pronation and supination of the hand, which is ensured by the two being performed at the same joint, is essential to the accuracy of the various minute movements of the hand.

The portion of the joint between the ulna and humerus is a simple hinge-joint, and allows of movements of flexion and extension only. Owing to the obliquity of the trochlea of the humerus, this movement does not take place in the antero-posterior plane of the body of the humerus. When the forearm is extended and supinated, the axes of the arm and forearm are not in the same line; the arm forms an obtuse angle with the forearm, the hand and forearm being directed laterally. During flexion, however, the forearm and the hand tend to approach the middle line of the body, and thus enable the hand to be easily carried to the face. The accurate adaptation of the trochlea of the humerus, with its prominences and depressions, to the semilunar notch of the ulna, prevents any lateral movement. *Flexion* is produced by the Biceps brachii and Brachialis, assisted by the Brachioradialis and the muscles arising from the medial condyle of the humerus; *extension* by the Triceps brachii and Anconæus, assisted by the Extensors of the wrist, the Extensor digitorum communis, and the Extensor digiti quinti proprius.

The joint between the head of the radius and the capitulum of the humerus is an arthrodial joint. The bony surfaces would of themselves constitute an enarthrosis and allow of movement in all directions, were it not for the annular ligament, by which the head of the radius is bound to the radial notch of the ulna, and which prevents any separation of the two bones laterally. It is to the same ligament that the head of the radius owes its security from dislocation, which would otherwise tend to occur, from the shallowness of the cup-like surface on the head of the radius. In fact, but for this ligament, the tendon of the Biceps brachii would be liable to pull the head of the radius out of the joint. The head of the radius is not in complete contact with the capitulum of the humerus in all positions of the joint. The capitulum occupies only the anterior and inferior surfaces of the lower end of the humerus, so that in complete extension a part of the radial head can be plainly felt projecting at the back of the articulation. In full flexion the movement of the radial head is hampered by the compression of the surrounding soft parts, so that the freest rotatory movement of the radius on the humerus (pronation and supination) takes place in semiflexion, in which position the two articular surfaces are in most intimate contact. Flexion and extension of the elbow-joint are limited by the tension of the structures on the front and back of the joint; the limitation of flexion is also aided by the soft structures of the arm and forearm coming into contact.

In any position of flexion or extension, the radius, carrying the hand with it, can be rotated in the proximal radio-ulnar joint. The hand is directly articulated to the lower surface of the radius only, and the ulnar notch on the lower end of the radius travels round the lower end of the ulna. The latter bone is excluded from the wrist-joint by the articular disc. Thus, rotation of the head of the radius round an axis passing through the centre of the radial head of the humerus imparts circular movement to the hand through a very considerable arc.

The movements in the distal radio-ulnar articulation consist of rotation of the lower end of the radius round an axis which passes through the centre of the head of the ulna. When the radius rotates forwards, *pronation* of the forearm and hand is the result; and when backwards, *supination*. It will thus be seen that in

pronation and supination the radius describes the segment of a cone, the axis of which extends from the centre of the head of the radius to the middle of the head of the ulna. In this movement the head of the ulna is not stationary, but describes a curve in a direction opposite to that taken by the head of the radius. This, however, is not to be regarded as a rotation of the ulna—the curve which the head of this bone describes is due to a combined anteroposterior and rotatory movement, the former taking place almost entirely at the elbow-joint, the latter at the shoulder-joint.

Applied Anatomy.—From the breadth of the elbow-joint, and the manner in which the articular surfaces are interlocked, and also on account of the strong collateral ligaments and the support which the joint derives from the mass of muscles attached to each epicondyle of the humerus, lateral displacement of the bones is very uncommon; whereas anteroposterior dislocation, on account of the shortness of the anteroposterior diameter, the weakness of the anterior and posterior parts of the articular capsule, and the want of support of muscles, occurs much more frequently. Dislocation backwards takes place when the forearm is in a position of extension, and forwards when in a position of flexion. For, in the extended position, the coronoid process is not locked into the coronoid fossa, and loses its grip to a certain extent, whereas the olecranon is in the olecranon fossa, and entirely prevents displacement forwards. On the other hand, during flexion, the coronoid process is in the coronoid fossa, and prevents dislocation backwards, while the olecranon, having left the olecranon fossa, is not so efficient in preventing a forward displacement. When lateral dislocation does take place it is generally incomplete. Dislocation of the elbow-joint is of common occurrence in children, far more common than dislocation of any other articulation. As a rule, in young persons, the application of any severe violence to a joint is more likely to produce a fracture of bone than dislocation. In lesions of this joint there is often very great difficulty in ascertaining the exact nature of the injury.

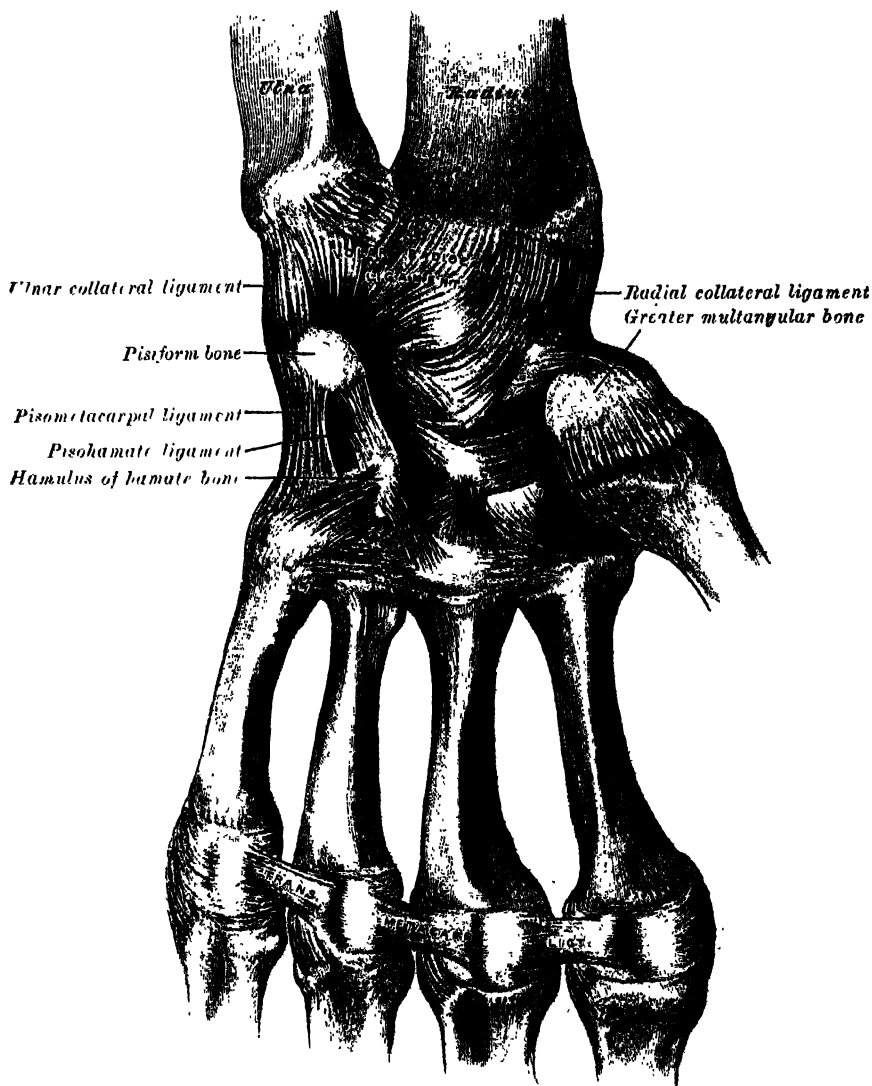
The elbow-joint is occasionally the seat of acute synovitis. The joint-cavity then becomes distended with fluid, the bulging showing itself principally around the olecranon, in consequence of the laxness of the articular capsule. Again, there is often some swelling just above the head of the radius, in the line of the radiohumeral joint, or the whole elbow may assume a fusiform appearance. There is not generally much swelling at the front of the joint, though sometimes deep-seated fulness beneath the *Brachialis* may be noted. When suppuration occurs the abscess usually points at one or other border of the *Triceps brachii*; occasionally the pus discharges itself in front, near the insertion of the *Brachialis*. In cases of suppurative synovitis, incisions should be made into the joint on either side of the olecranon, care being taken to avoid wounding the ulnar nerve on the medial side. Chronic synovitis, usually of tuberculous origin, is of common occurrence in the elbow-joint; in such cases the forearm tends to assume the position of semiflexion, which is that of greatest ease and relaxation of ligaments. It should be borne in mind that if ankylosis occur in this or the extended position, the limb will not be nearly so useful as if ankylosed in a position of rather less than a right angle. The elbow-joint is also sometimes affected with osteo-arthritis, but less commonly than some of the larger joints.

Excision of the elbow is principally required for one of three conditions—viz. tuberculous arthritis, injury and its results, or faulty ankylosis—but may be necessary for some other rarer conditions, such as disorganising arthritis after pyæmia and unreduced dislocations. The results of the operation are, as a rule, more favourable than those of excision of any other joint, especially in any of the first three conditions mentioned above. The operation is best performed by a vertical incision down the back of the joint; a straight incision is made about 10 cm. long, the mid-point of which is on a level with and a little to the medial side of the tip of the olecranon. This incision is made down to the bone, through the substance of the *Triceps brachii*. The operator, guarding the soft parts with his thumb-nail, separates them from the bone with the point of his knife. In doing this there are two structures which he should carefully avoid: the ulnar nerve, which as it courses down between the medial epicondyle and the olecranon lies parallel but a little medially to his incision; and the prolongation of the *Triceps brachii* into the deep fascia of the forearm over the *Anconeus*. After clearing the bones and dividing the collateral and posterior ligaments, the forearm should be strongly flexed and the ends of the bones turned out and sawn off. The turning out of the ends of the bones is rendered easier by first cutting off the olecranon with a pair of cutting bone forceps. The section of the humerus should be through the base of the epicondyles, that of the ulna and radius should be just below the level of the radial notch of the ulna and the neck of the radius. In this operation the object is to obtain such union as shall allow free motion of the bones of the forearm; and, therefore, passive movements must be commenced early—that is to say, about the tenth day. It is most important to maintain the continuity of the *Triceps brachii* with the deep fascia of the forearm, so as to obtain good power of extension in the new joint.

Dislocation of the head of the radius alone is a not uncommon accident, and occurs most frequently in young persons from falls on the hand when the forearm is extended and supinated, the head of the bone being displaced forward. It is attended by rupture

of the annular ligament. Occasionally a peculiar injury, which is supposed to be a subluxation, occurs in young children in lifting them from the ground by the hand or forearm. It is believed that the head of the radius is displaced downwards in the annular ligament, the upper border of which becomes folded over the head of the radius, between it and the capitulum of the humerus. The forearm becomes fixed in a position of semiflexion, midway between supination and pronation, and great pain is complained

FIG. 481.—Ligaments of wrist and metacarpus. Anterior view.



of upon any attempt to move the joint. The synovial stratum of the proximal radio-ulnar joint is directly continuous with that of the elbow-joint, and, therefore, any septic or tuberculous disease which affects the latter also involves the former joint. The proximal radio-ulnar joint is always removed in an excision of the elbow (see preceding paragraph).

VI. RADIOCARPAL ARTICULATION OR WRIST-JOINT

The radiocarpal articulation or wrist-joint (figs. 481, 482) is a condyloid articulation. The parts forming it are the distal end of the radius and under surface of the articular disc above; and the navicular, lunate, and triquetral bones below. The articular surface of the radius and the under surface of the

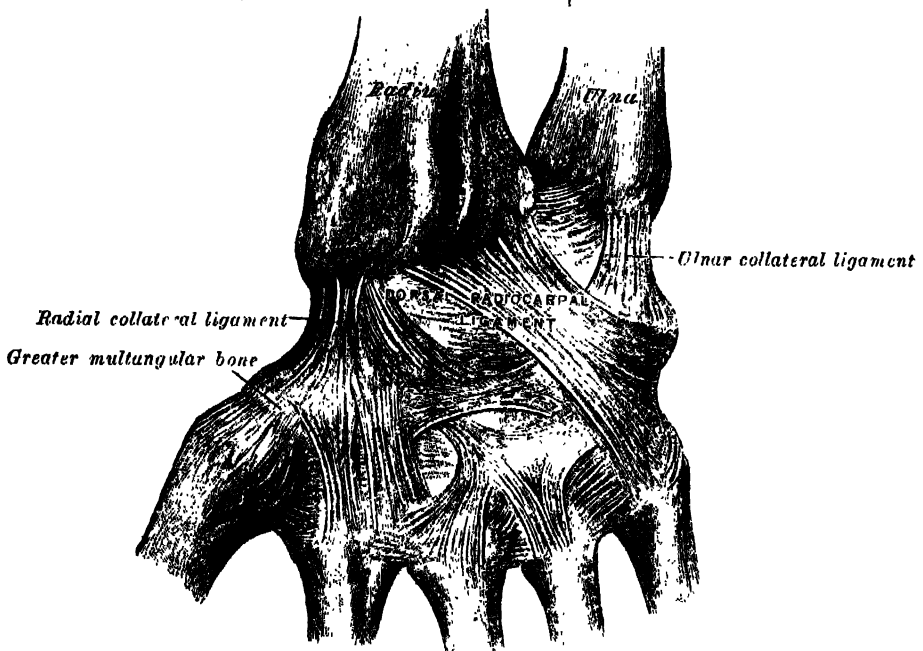
articular disc form together a transversely elliptical concave surface, the *receiving cavity*. The proximal articular surfaces of the navicular, lunate, and triquetral bones form a smooth convex surface, the *condyle*, which is received into the concavity. The joint is surrounded by an **articular capsule**. The *synovial stratum* of the capsule is usually distinct from that of the distal radio-ulnar joint and from that of the carpal joints; the *fibrous stratum* is strengthened by the following ligaments:

Volar radiocarpal.
Dorsal radiocarpal.

Ulnar collateral.
Radial collateral.

The **volar radiocarpal ligament** (fig. 481) is a broad membranous band, attached above to the anterior margin of the distal end of the radius, to its styloid process, and to the front of the distal end of the ulna; its fibres pass

FIG. 482.—Ligaments of wrist. Posterior view.



downwards and medialwards to be attached to the volar surfaces of the navicular, lunate, and triquetral bones, some being continued to the capitate bone. In addition to this broad membrane, there is a rounded fasciculus, superficial to the rest, which reaches from the base of the styloid process of the ulna to the lunate and triquetral bones. The ligament is perforated by apertures for the passage of vessels, and is in relation, in front, with the tendons of the Flexor digitorum profundus and Flexor pollicis longus; behind, it is closely adherent to the anterior border of the articular disc of the distal radio-ulnar articulation.

The **dorsal radiocarpal ligament** (fig. 482), less thick and strong than the volar, is attached, above, to the posterior border of the distal end of the radius; its fibres are directed obliquely downwards and medialwards, and are fixed, below, to the dorsal surfaces of the navicular, lunate, and triquetral bones, being continuous with those of the dorsal intercarpal ligaments. It is in relation, behind, with the Extensor tendons of the fingers; in front, it is blended with the articular disc of the distal radio-ulnar articulation.

The **ulnar collateral ligament** (internal lateral ligament) (fig. 481) is attached above to the end of the styloid process of the ulna, and divided below into two fasciculi, one of which is attached to the medial side of the triquetral bone, the other to the pisiform bone.

The **radial collateral ligament** (external lateral ligament) (fig. 481) extends from the tip of the styloid process of the radius to the radial side of the navicular bone, some of its fibres being prolonged to the greater multangular bone. It is in relation with the radial artery, which separates the ligament from the tendons of the *Abductor pollicis longus* and *Extensor pollicis brevis*.

The *arteries* supplying the joint are the volar interosseous, the volar and dorsal carpal branches of the radial and ulnar, the volar and dorsal metacarpals, and some recurrent branches from the deep volar arch. The *nerves* are derived from the ulnar and dorsal interosseous nerves.

Movements.--The movements permitted in this joint are flexion, extension, abduction, adduction, and circumduction. They will be studied with those of the carpus, with which they are combined.

VII. INTERCARPAL ARTICULATIONS

These articulations may be subdivided into three sets: (1) those of the proximal row of carpal bones; (2) those of the distal row of carpal bones; and (3) those of the two rows with each other.

1. ARTICULATIONS OF THE PROXIMAL ROW OF CARPAL BONES

These are arthrodial joints. The navicular, lunate, and triquetral are connected by dorsal, volar, and interosseous ligaments.

The **dorsal and volar ligaments**, two of each, are placed transversely between the bones of the first row; they connect the navicular and lunate bones, and the lunate and triquetral bones. The volar ligaments are weaker than the dorsal.

The **interosseous ligaments** (fig. 483) are two narrow bundles, one connecting the lunate bone with the navicular bone, the other joining the lunate bone to the triquetral bone. They are on a level with the proximal surfaces of these bones, and their proximal ends are smooth, and form part of the convex articular surface of the radiocarpal joint.

The ligaments of the pisiform bone are an articular capsule, the pisohamate and the pisometacarpal ligaments.

The **articular capsule** is thin and connects the pisiform to the triquetral. Its synovial stratum is distinct from that of the other carpal joints.

The **pisohamate ligament** connects the pisiform bone to the hamate bone, and the **pisometacarpal ligament** joins the pisiform bone to the base of the fifth metacarpal bone (fig. 481). These two ligaments are, in reality, prolongations of the tendon of the *Flexor carpi ulnaris*.

2. ARTICULATIONS OF THE DISTAL ROW OF CARPAL BONES

These also are arthrodial joints; the bones are connected by dorsal, volar, and interosseous ligaments.

The **dorsal and volar ligaments**, each three in number, extend transversely from one bone to another; one connects the greater and lesser multangular bones, a second the lesser multangular and capitate bones, and a third the capitate and hamate bones.

The three **interosseous ligaments** are much thicker than those of the proximal row; one unites the capitate and hamate bones, a second the capitate and lesser multangular bones, and a third the greater and lesser multangular bones. The first is the strongest; the third is sometimes wanting.

3. ARTICULATIONS OF THE TWO ROWS OF CARPAL BONES WITH EACH OTHER

The joint between the navicular, lunate, and triquetral bones on the one hand, and the second row of carpal bones on the other, is named the *mid-carpal joint*, and is made up of three portions: in the centre the head of the capitate

Movements.—The articulation of the hand and forearm considered as a whole involves four articular surfaces: (a) the inferior surfaces of the radius and articular disc; (b) the superior surfaces of the navicular, lunate, and triquetral bones, the pisiform bone having no essential part in the movement of the hand; (c) the S-shaped surface formed by the inferior surfaces of the navicular, lunate, and triquetral bones; (d) the reciprocal surface formed by the upper surfaces of the bones of the second row. These four surfaces form two joints: (1) a proximal, the radiocarpal; and (2) a distal, the mid-carpal joint.

(1) The radiocarpal joint is a true condyloid articulation, and therefore all movements but rotation are permitted. Flexion and extension are the most free, and of these a greater amount of extension than of flexion is permitted, since the articulating surfaces extend farther on the dorsal than on the volar surfaces of the carpal bones. In this movement the carpal bones rotate on a transverse axis drawn between the tips of the styloid processes of the radius and ulna. Adduction or ulnar flexion, and abduction or radial flexion are also permitted. The former is considerably greater in extent than the latter on account of the shortness of the styloid process of the ulna, abduction being soon limited by the contact of the styloid process of the radius with the greater multangular bone. In this movement the carpus revolves upon an anteroposterior axis drawn through the centre of the wrist.* Finally, circumduction is permitted by the combined and consecutive movements of adduction, extension, abduction, and flexion. No rotation is possible, but the effect of rotation is obtained by the pronation and supination of the radius on the ulna. The movement of *flexion* is performed by the Flexor carpi radialis, the Flexor carpi ulnaris, and the Palmaris longus; *extension* by the Extensores carpi radiales longus and brevis and the Extensor carpi ulnaris; *adduction* (ulnar flexion) by the Flexor carpi ulnaris and the Extensor carpi ulnaris; and *abduction* (radial flexion) by the Abductor pollicis longus, the Extensors of the thumb, and the Extensores carpi radiales longus and brevis and the Flexor carpi radialis. When the fingers are extended, flexion of the wrist is performed by the Flexores carpi radialis and ulnaris and extension by the Extensor digitorum communis. When the fingers are flexed, flexion of the wrist is performed by the Flexores digitorum sublimis and profundis, and extension by the Extensores carpi radiales and ulnaris.

(2) The chief movements permitted in the mid-carpal joint are flexion and extension and a slight amount of rotation. In flexion and extension, which are the movements most freely enjoyed, the greater and lesser multangular bones on the radial side and the hamate bone on the ulnar side glide forwards and backwards on the navicular and triquetral bones respectively, while the head of the capitate bone and the superior surface of the hamate bone rotate in the cup-shaped cavity of the navicular and lunate bones. Flexion at this joint is freer than extension. A very trifling amount of rotation is also permitted, the head of the capitate bone rotating round a vertical axis drawn through its own centre, while at the same time a slight gliding movement takes place in the lateral and medial portions of the joint.

Applied Anatomy.—The radiocarpal joint is rarely dislocated, its strength depending mainly upon the numerous strong tendons which surround the articulation. Its security is further provided for by the number of small bones of which the carpus is made up, and which are united by very strong ligaments. The slight movements which take place between the several bones serve to break the jars that result from falls or blows on the hand. Dislocation backwards, which is the more common, simulates to a considerable extent Colles's fracture of the radius, and is liable to be mistaken for it. The differential diagnosis can be easily made by observing the relative positions of the styloid processes of the radius and the ulna. In the natural condition when the arm hangs by the side, the styloid process of the radius is on a lower level, i.e. nearer the ground, than that of the ulna, and this relationship is not disturbed in dislocation. In Colles's fracture, the styloid process of the radius is on the same level as, or even on a higher level than, that of the ulna.

The radiocarpal joint is occasionally the seat of acute synovitis. When the joint cavity is distended with fluid, the swelling is greatest on the dorsal aspect of the wrist, showing a general fulness, with some bulging between the tendons. The inflammation is prone to extend to the intercarpal joints and to attack also the sheaths of the tendons in the neighbourhood. Chronic inflammation of the wrist is generally tuberculous, and often leads to similar disease in the mucous sheaths of adjacent tendons and the intercarpal joints, with resulting ankylosis.

* H. M. Johnston (*Journal of Anatomy and Physiology*, vol. xli.) maintains that in ulnar and radial flexion only slight lateral movement occurs at the radiocarpal joint, and that in complete flexion and extension of the hand there is a small degree of ulnar flexion at the radiocarpal joint.

VIII. CARPOMETACARPAL ARTICULATIONS

1. CARPOMETACARPAL ARTICULATION OF THE THUMB

This is a joint of reciprocal reception between the first metacarpal and greater multangular bones; it enjoys great freedom of movement on account of the configuration of its articular surfaces, which are saddle-shaped. The joint is surrounded by an **articular capsule** which is thick but loose, and passes from the circumference of the base of the metacarpal bone to the rough edge bounding the articular surface of the greater multangular bone; it is thickest laterally and dorsally. A synovial stratum lines the capsule and is quite distinct from that of the other carpometacarpal joints.

Movements.—In this articulation the movements permitted are flexion and extension in the plane of the palm of the hand, abduction and adduction in a plane at right angles to the palm, circumduction, and opposition. It is by the movement of opposition that the tip of the thumb is brought into contact with the volar surfaces of the slightly flexed fingers. This movement is effected through the medium of a small sloping facet on the anterior lip of the saddle-shaped articular surface of the greater multangular bone. The flexor muscles pull the corresponding part of the articular surface of the metacarpal bone on to this facet, and the movement of opposition is then carried out by the adductor muscles.

Flexion of this joint is produced by the *Flexores pollicis longus* and *brevis*, assisted by the *Opponens pollicis* and the *Adductor pollicis*. Extension is effected mainly by the *Abductor pollicis longus*, assisted by the *Extensores pollicis longus* and *brevis*. Adduction is carried out by the *Adductor pollicis*; abduction mainly by the *Abductores pollicis longus* and *brevis*, assisted by the extensor muscles.

2. ARTICULATIONS OF THE SECOND, THIRD, AND FOURTH METACARPAL BONES WITH THE CARPUS

The joints between the carpus and the second, third, fourth, and fifth metacarpal bones are arthrodial. The bones are united by articular capsules, strengthened by dorsal, volar, and interosseous ligaments.

The **dorsal ligaments**, the strongest and most distinct, connect the carpal and metacarpal bones on their dorsal surfaces. The second metacarpal bone receives two fasciculi, one each from the greater and lesser multangular bones; the third metacarpal receives two, one each from the lesser multangular and capitate bones; the fourth two, one each from the capitate and hamate bones; the fifth receives a single fasciculus from the hamate bone, and this is continuous with a similar ligament on the volar surface, forming an incomplete fibrous capsule.

The **volar ligaments** have a somewhat similar arrangement, with the exception of those of the third metacarpal, which are three in number: a lateral one from the greater multangular bone, situated superficially to the sheath of the tendon of the *Flexor carpi radialis*; an intermediate one from the capitate bone; and a medial one from the hamate bone.

The **interosseous ligaments** consist of short, thick fibres, and are limited to one part of the carpometacarpal articulation; they connect the contiguous inferior angles of the capitate and hamate bones with the adjacent surfaces of the third and fourth metacarpal bones.

The **synovial stratum** of the articular capsules is a continuation of that of the intercarpal joints. Occasionally, the joint between the hamate bone and the fourth and fifth metacarpal bones has a separate synovial stratum.

Movements.—The movements permitted in the carpometacarpal articulations of the fingers are limited to slight gliding of the articular surfaces upon each other, the extent of which varies in the different joints. The metacarpal bone of the little finger is the most movable, then that of the ring-finger; the metacarpal bones of the index and middle fingers are almost immovable.

IX. INTERMETACARPAL ARTICULATIONS

The bases of the second, third, fourth, and fifth metacarpal bones articulate with one another by small surfaces covered with cartilage, and are connected together by dorsal, volar, and interosseous ligaments.

The **dorsal** and **volar ligaments** pass transversely from one bone to another on the dorsal and volar surfaces. The **interosseous ligaments** connect their contiguous surfaces, just distal to their collateral articular facets.

The **synovial stratum** of these joints is continuous with that of the carpo-metacarpal articulations.

The **transverse metacarpal ligament** (fig. 482) is a narrow fibrous band, which runs across the volar surfaces of the heads of the second, third, fourth, and fifth metacarpal bones, connecting them together. It is blended with the accessory volar ligaments (glenoid ligaments) of the metacarpophalangeal articulations. Its volar surface is grooved where the flexor tendons pass over it; behind the ligament the tendons of the Interossei pass to their insertions.

X. METACARPOPHALANGEAL ARTICULATIONS (figs. 484, 485)

These articulations are of the condyloid kind, formed by the reception of the rounded heads of the metacarpal bones into shallow cavities on the proximal

FIG. 484.—Metacarpophalangeal articulation and articulations of digit. Volar aspect.

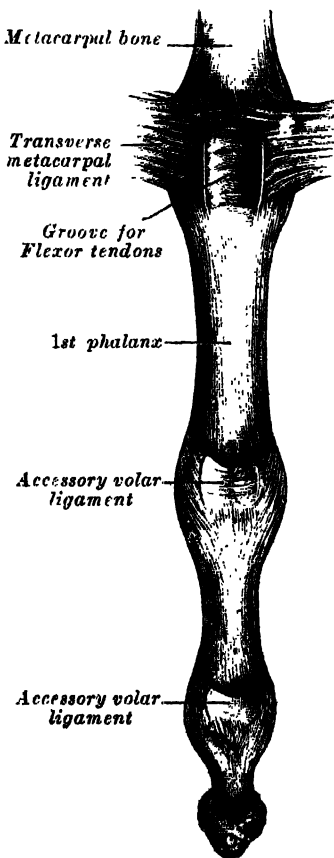
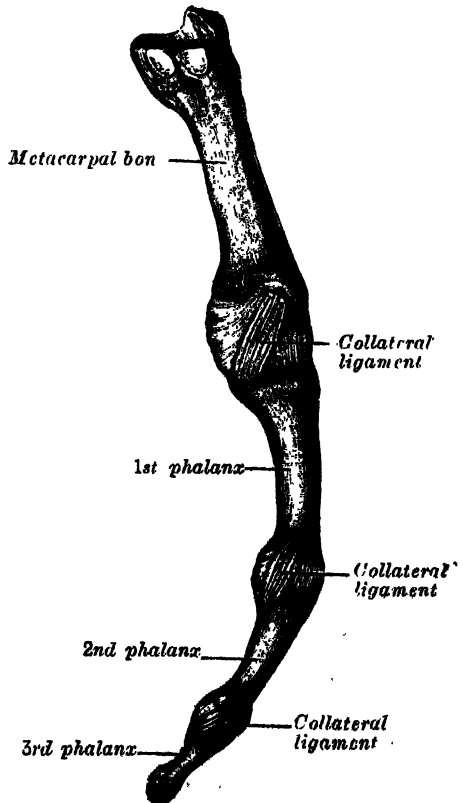


FIG. 485.—Metacarpophalangeal articulation and articulations of digit. Ulnar aspect.



ends of the first phalanges, with the exception of that of the thumb, which presents more of the characters of a ginglymoid joint. Each joint has an accessory volar and two collateral ligaments.

ARTICULATIONS OF THE LOWER EXTREMITY

The **accessory volar ligaments** (*glenoid ligaments* of Cruveilhier) are thick, dense, fibrocartilaginous structures, placed upon the volar surfaces of the joints in the intervals between the collateral ligaments, to which they are connected; they are loosely united to the metacarpal bones, but are very firmly attached to the bases of the first phalanges. Their volar surfaces are intimately blended with the transverse metacarpal ligament, and grooved for the flexor tendons, the sheaths surrounding which are connected to the sides of the grooves. Their deep surfaces form parts of the articular facets for the heads of the metacarpal bones.

The **collateral ligaments** are strong, rounded cords, placed on the sides of the joints; each is attached by one extremity to the posterior tubercle and adjacent depression on the side of the head of the metacarpal bone, and by the other to the contiguous extremity of the phalanx.

The dorsal surfaces of these joints are covered by the expansions of the extensor tendons, together with some loose areolar tissue which connects the deep surfaces of the tendons to the bones.

Movements.—The movements which occur in these joints are flexion, extension, adduction, abduction, and circumduction; the movements of abduction and adduction are very limited, and cannot be performed when the fingers are flexed.

XI. DIGITAL ARTICULATIONS

The interphalangeal articulations are hinge-joints; each has a volar and two collateral ligaments. The arrangement of these ligaments is similar to those in the metacarpophalangeal articulations. The extensor tendons supply the places of posterior ligaments.

Movements.—The only movements permitted in the interphalangeal joints are flexion and extension; these movements are more extensive between the first and second phalanges than between the second and third. The amount of flexion is very considerable, but extension is limited by the volar and collateral ligaments.

MUSCLES ACTING ON THE JOINTS OF THE DIGITS

Flexion of the metacarpophalangeal joints of the fingers is effected by the *Flexores digitorum sublimis* and *profundus*, *Lumbricales*, and *Interossei*, assisted in the case of the little finger by the *Flexor digiti quinti brevis*. Extension is produced by the *Extensor digitorum communis*, *Extensor indicis proprius*, and *Extensor digiti quinti proprius*.

Flexion of the interphalangeal joints of the fingers is accomplished by the *Flexor digitorum profundus* acting on the proximal and distal joints and by the *Flexor digitorum sublimis* acting on the proximal joints. Extension is effected mainly by the *Lumbricales* and *Interossei*, the long extensors having little or no action upon these joints.

Flexion of the metacarpophalangeal joint of the thumb is effected by the *Flexores pollicis longus* and *brevis*; extension by the *Extensores pollicis longus* and *brevis*. Flexion of the interphalangeal joint is accomplished by the *Flexor pollicis longus*, and extension by the *Extensor pollicis longus*.

ARTICULATIONS OF THE LOWER EXTREMITY

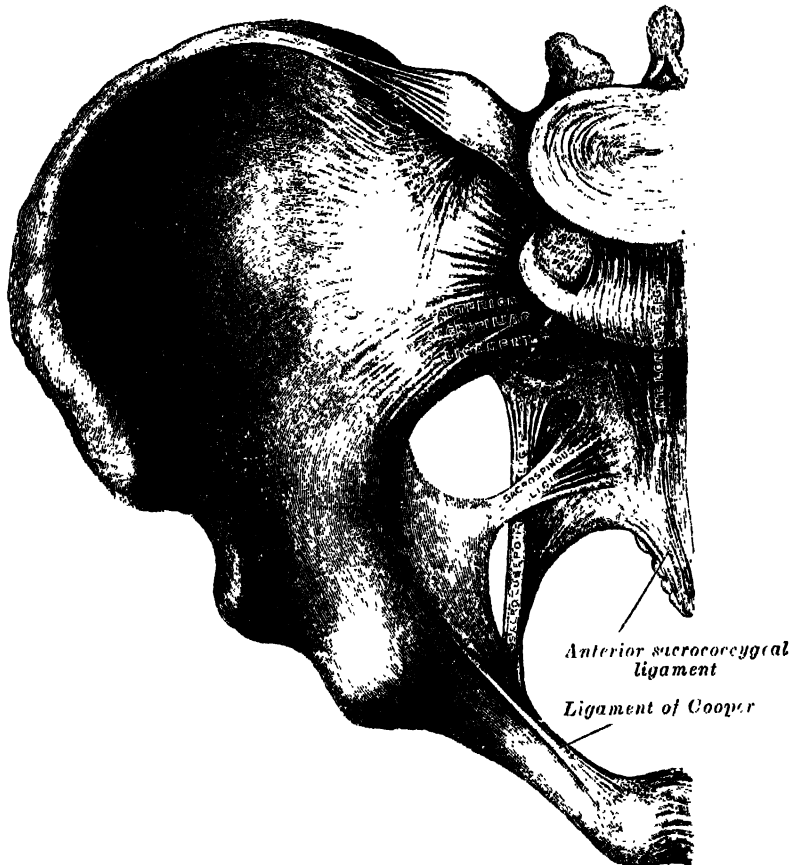
The articulations of the lower extremity comprise the following:

- | | |
|----------------------|-------------------------|
| I. Sacro-iliac. | VI. Ankle. |
| II. Pubic symphysis. | VII. Intertarsal. |
| III. Hip. | VIII. Tarsometatarsal. |
| IV. Knee. | IX. Intermetatarsal. |
| V. Tibiofibular. | X. Metatarsophalangeal. |
| XI. Digital. | |

I. SACRO-ILIAIC ARTICULATION

The sacro-iliac articulation is an amphiarthrodial joint, formed between the auricular surfaces of the sacrum and ilium. The articular surface of each bone is covered with a plate of cartilage which is thicker on the sacrum than on the ilium. These plates are in close contact with each other, and to a certain extent are united by irregular patches of softer fibrocartilage, and at their upper and posterior part by fine interosseous fibres. In a considerable portion

FIG. 486. Articulations of pelvis. Anterosuperior view.



of their extent, especially in advanced life, they are separated by a space containing a synovia-like fluid, and hence part of the joint presents the characteristics of a diarthrosis. The ligaments of the joint are :

Anterior sacro-iliac. Posterior sacro-iliac.
Interosseous sacro-iliac.

The **anterior sacro-iliac ligament** (fig. 486) consists of numerous thin bands, which connect the anterior surface of the lateral part of the sacrum to the margin of the auricular surface of the ilium and to the pre-auricular sulcus.

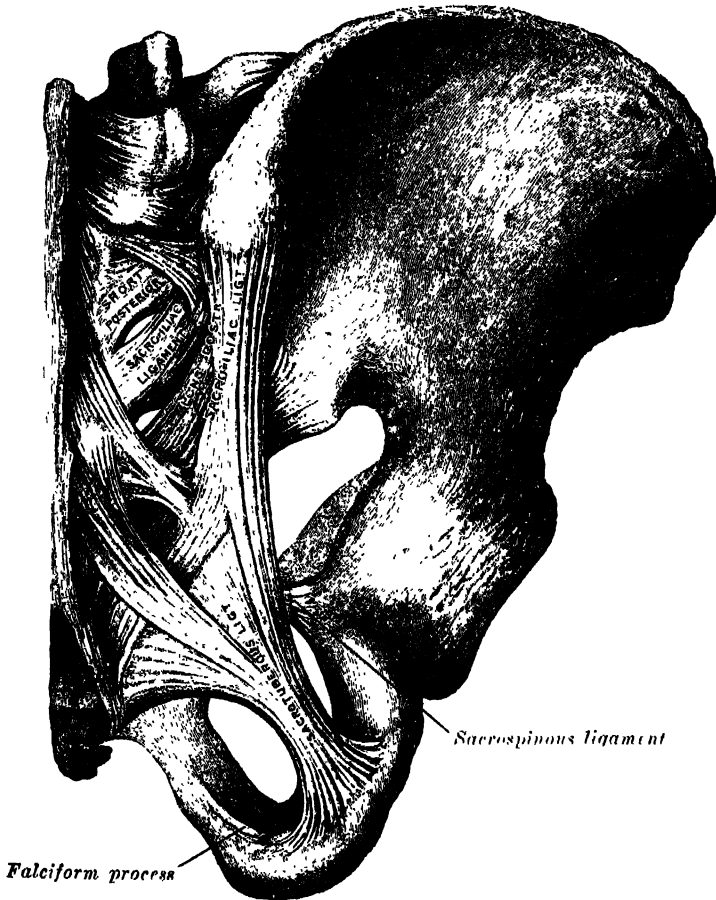
The **posterior sacro-iliac ligament** (fig. 487) is situated in a deep depression between the sacrum and ilium behind ; it is strong and forms the chief bond of union between the bones. Its upper part, the *short posterior sacro-iliac ligament*, is nearly horizontal in direction, and passes from the first and second transverse tubercles on the back of the sacrum to the iliac tuberosity above and behind the auricular surface. Its lower part, the *long posterior sacro-iliac ligament*, is oblique in direction ; it is attached above to the third transverse tubercle of the back of the sacrum, where it is blended with the upper and

medial part of the sacrotuberous ligament, below, to the posterior superior spine of the ilium.

The **interosseous sacro-iliac ligament** lies deep to the posterior sacro-iliac ligament, and consists of a series of short, strong fibres connecting the iliac and sacral tuberosities.

The ilium is connected to the fifth lumbar vertebra by the *iliolumbar ligament*, and the sacrum to the ischium by the *sacrotuberous* and *sacrospinous ligaments*.

FIG. 487.—Articulations of pelvis. Posterior view.



The **iliolumbar ligament** (fig. 486) is attached above to the lower and front part of the transverse process of the fifth lumbar vertebra, and occasionally has an additional, weak attachment to the transverse process of the fourth. It radiates as it passes lateralwards and is attached by two main bands to the pelvis. The lower band runs to the ala of the ilium and the base of the sacrum, blending with the anterior sacro-iliac ligament: the upper is attached to the crest of the ilium immediately in front of the sacro-iliac articulation and is continuous above with the lumbodorsal fascia.

The **sacrotuberous ligament** (great sacrospinous ligament) (fig. 487) is placed at the lower and posterior part of the pelvis. It is flat, and somewhat triangular in form; it is attached by its broad base to the posterior inferior spine of the ilium, to the third, fourth, and fifth transverse tubercles of the sacrum, and to the lower part of the lateral margin of that bone and the coccyx. Passing obliquely downwards, forwards, and lateralwards, it becomes narrow and thick, but at its insertion into the inner margin of the tuberosity of the ischium it increases in breadth, and is prolonged forwards along the inner margin of the ramus as the *falciform process*, the free concave edge of which gives attachment

to the fascia of the Obturator internus. The lower border of the ligament is directly continuous with the tendon of origin of the long head of the Biceps femoris.

The **sacrospinous ligament** (small sacrosciatic ligament) (fig. 486) is thin, and triangular in form; it is attached by its apex to the spine of the ischium, and, medially, by its broad base, to the lateral margins of the sacrum and coccyx, in front of the sacrotuberous ligament, with which its fibres are intermingled. It is in relation in front with the Coccygeus muscle, to which it is closely connected, and of which it may represent a degenerated part.

These two ligaments convert the sciatic notches into foramina. The *greater sciatic foramen* is bounded, in front and above, by the greater sciatic notch: behind, by the sacrotuberous ligament; and below, by the sacrospinous ligament and the spine of the ischium. It is partially filled up, in the recent state, by the Piriformis muscle which emerges from the pelvis through it. Above this muscle, the superior gluteal vessels and nerve pass out of the pelvis; and below it, the inferior gluteal vessels and nerve, the internal pudendal vessels and nerve, the sciatic and posterior femoral cutaneous nerves, and the nerves to the Obturator internus and Quadratus femoris make their exit from the pelvis. The *lesser sciatic foramen* is bounded, in front, by the superior ramus of the ischium; above, by the spine of the ischium and sacrospinous ligament: behind, by the sacrotuberous ligament. It transmits the tendon of the Obturator internus, its nerve, and the internal pudendal vessels and nerve.

II. PUBIC SYMPHYSIS

The ligaments of the pubic symphysis are :

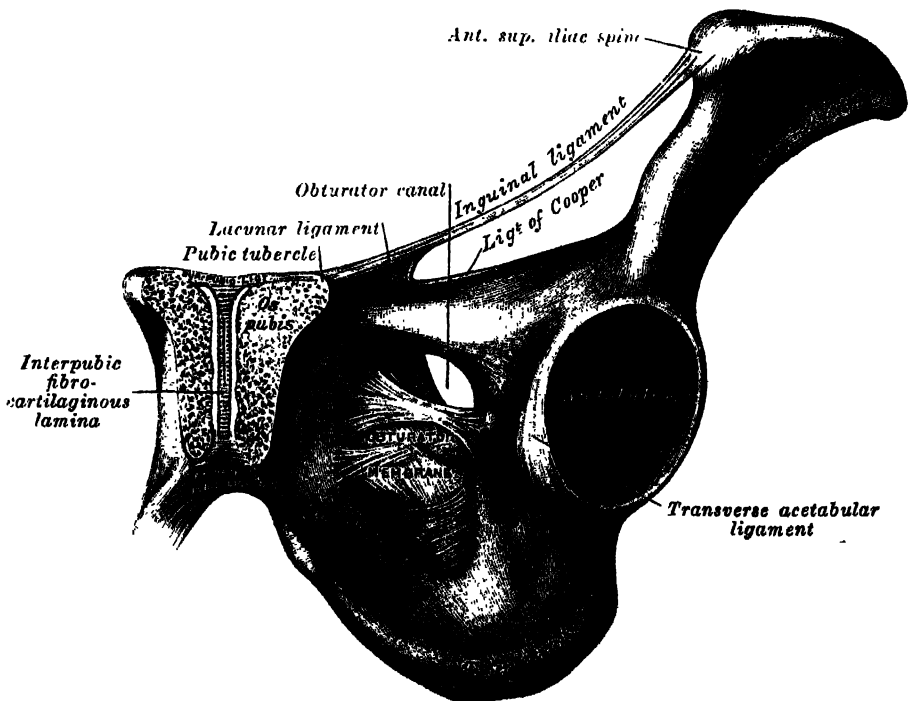
Superior pubic.

Arcuate pubic.

Interpubic fibrocartilaginous lamina.

The **superior pubic ligament** connects together the two pubic bones superiorly, and extends as far as the pubic tubercles.

FIG. 488.-- Pubic symphysis exposed by a coronal section.



The **arcuate pubic ligament** (inferior or subpubic ligament) is a thick, triangular arch of fibres, connecting the two pubic bones below, and forming the upper boundary of the pubic arch. Above, it is blended with the interpubic

fibrocartilaginous lamina; laterally, it is attached to the inferior rami of the pubic bones; below, it is free, and is separated from the fascia of the urogenital diaphragm by an opening through which, in the male, the deep dorsal vein of the penis enters the pelvis.

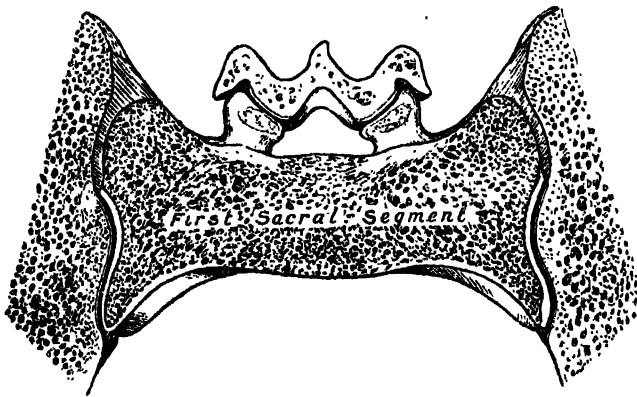
The **interpubic fibrocartilaginous lamina** connects the opposed surfaces of the pubic bones. Each of these surfaces is covered by a thin layer of hyaline cartilage firmly joined to the bone by a series of nipple-like processes which accurately fit into corresponding depressions on the osseous surfaces. These opposed cartilaginous surfaces are connected together by a lamina of fibrocartilage which varies in thickness in different subjects. It often contains a cavity in its interior, probably formed by the softening and absorption of the fibrocartilage, since it rarely appears before the tenth year of life and is not lined by a synovial stratum. This cavity is usually limited to the upper and back part of the joint; it occasionally reaches the front, and may extend the entire length of the cartilage. It may be easily demonstrated when present by making a coronal section of the symphysis pubis near its posterior surface (fig. 488). In front, the lamina is strengthened by several superimposed layers of fibres, which pass obliquely from one bone to the other, decussating and forming an interlacement with the fibres of the aponeuroses of the *Obliqui externi* and the medial tendons of origin of the *Recti abdominis*.

MECHANISM OF THE PELVIS

The pelvic girdle supports and protects the contained viscera and affords surfaces for the attachments of the muscles of the trunk and lower limb. Its most important mechanical function, however, is to transmit the weight of the trunk and upper limbs to the lower extremities.

It may be divided into two arches by a vertical plane passing through the acetabular cavities; the posterior of these arches is the one chiefly concerned in the function of transmitting the weight. Its essential parts are the upper three sacral vertebrae and two strong pillars of bone running from the sacro-iliac articulations

FIG. 489.—Coronal section of anterior sacral segment.

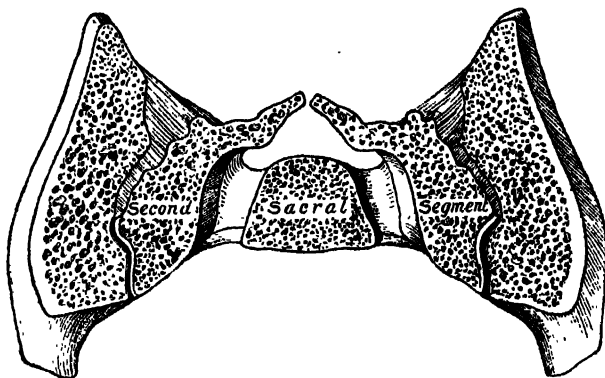


to the acetabular cavities. For the reception and diffusion of the weight each acetabular cavity is strengthened by two additional bars running towards the os pubis and the ischium. In order to lessen concussion in rapid changes of distribution of the weight, joints (sacro-iliac articulations) are interposed between the sacrum and the iliac bones; an accessory joint (symphysis pubis) exists in the middle of the anterior arch. The sacrum forms the summit of the posterior arch; the weight transmitted falls on it at the lumbosacral articulation and, theoretically, has a component in each of two directions. One component of the force is expended in driving the sacrum downwards and backwards between the iliac bones, while the other thrusts the upper end of the sacrum downwards and forwards towards the pelvic cavity.

The movements of the sacrum are regulated by its form. Viewed as a whole, it presents the shape of a wedge with its base upwards and forwards. The first component of the force is therefore acting against the resistance of the wedge, and its tendency to separate the iliac bones is resisted by the sacro-iliac and iliolumbar ligaments and by the ligaments of the symphysis pubis.

If a series of coronal sections of the sacro-iliac joints be made, it will be found possible to divide the articular portion of the sacrum into three segments: anterior, middle, and posterior. In the *anterior segment* (fig. 489), which involves the first sacral vertebra, the articular surfaces show slight sinuositics and are almost parallel

FIG. 490.—Coronal section of middle sacral segment.



to one another; the distance between their dorsal margins is, however, slightly greater than that between their ventral margins. This segment therefore presents a slightly wedge-shape with the truncated apex downwards. The *middle segment* (fig. 490) is a narrow bar across the centres of the articulations. Its dorsal width is distinctly greater than its ventral, so that the segment is more definitely wedge-shaped, the truncated apex being again directed downwards. Each sacral articular surface presents in the centre a marked concavity from above downwards, and into this a corresponding convexity of the iliac articular surface fits, forming an interlocking mechanism. In the *posterior segment* (fig. 491) the ventral width is greater than the dorsal, so that the wedge-form is the reverse of those of the other segments.

FIG. 491.—Coronal section of posterior sacral segment.



--i.e. the truncated apex is directed upwards. The articular surfaces are only slightly concave.

Dislocation downwards and forwards of the sacrum by the second component of the force applied to it is prevented therefore by the middle segment, which interposes the resistance of its wedge shape and that of the interlocking mechanism on its surfaces; a rotatory movement, however, is produced by which the anterior segment is tilted downwards and the posterior

upwards: the axis of this rotation passes through the dorsal part of the middle segment. The movement of the anterior segment is slightly limited by its wedge-form, but chiefly by the posterior and interosseous sacro-iliac ligaments; that of the posterior segment is checked to a slight extent by its wedge-form, but the chief limiting factors are the sacrotuberous and sacrospinous ligaments. In all these movements the effect of the sacro-iliac and iliolumbar ligaments and the ligaments of the symphysis pubis in resisting the separation of the iliac bones must be recognised.

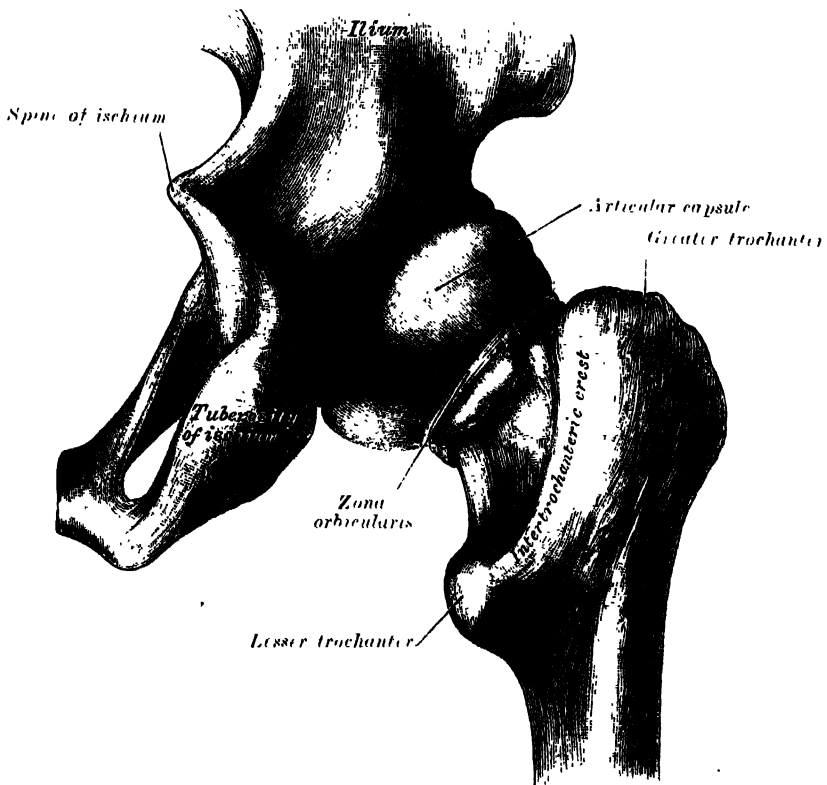
During pregnancy the pelvic joints and ligaments are relaxed, and capable therefore of more extensive movements. When the foetus is being expelled the force is applied to the front of the sacrum. Upward dislocation is prevented by

the interlocking mechanism of the middle segment. As the foetal head passes the anterior segment the latter is carried upwards, enlarging the anteroposterior diameter of the pelvic inlet; when the head reaches the posterior segment this also is pressed upwards against the resistance of its wedge, the movement only being possible by the laxity of the joints and the stretching of the sacrotuberous and sacrospinous ligaments.

III. COXAL ARTICULATION OR HIP-JOINT

The hip-joint is an enarthrodial, or ball-and-socket articulation, formed by the reception of the head of the femur into the cup-shaped cavity of the acetabulum. The articular cartilage on the head of the femur, thicker at the centre than at the circumference, covers the entire surface with the exception

FIG. 492.—Articular capsule of hip-joint (distended). Posterior aspect.



of the fovea capitis femoris, to which the ligamentum teres is attached; that on the acetabulum forms an incomplete ring, the lunate surface. Within the lunate surface there is a circular depression devoid of cartilage, occupied in the recent state by a mass of fat covered by the synovial stratum of the articular capsule. The ligaments of the joint are:

The articular capsule.
Iliofemoral.
Ischiocapsular.

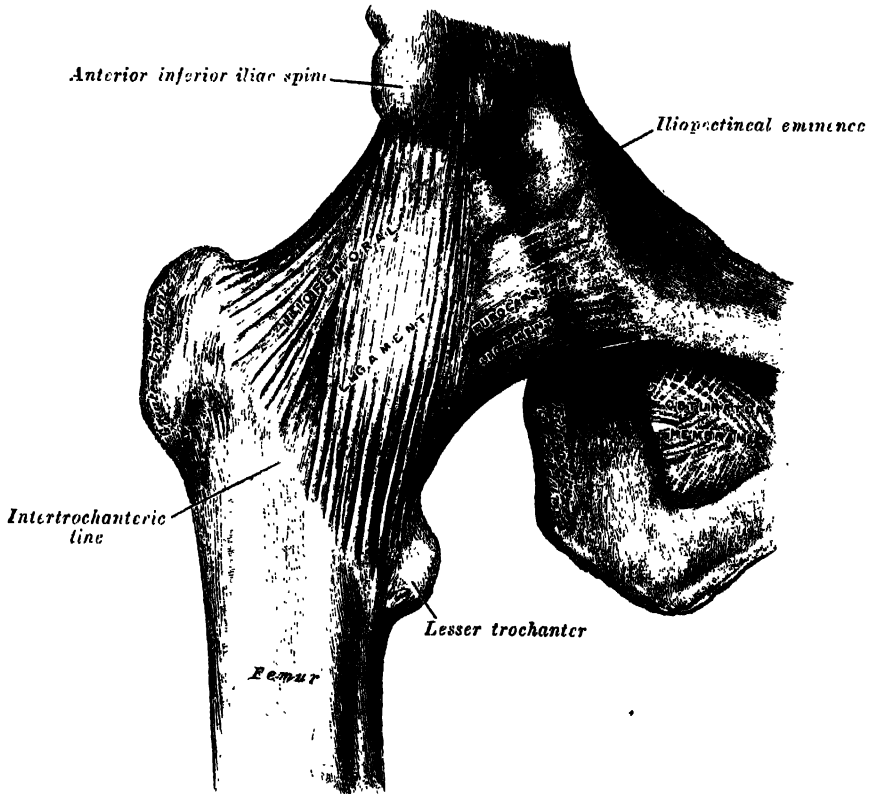
Pubocapsular.
Ligamentum teres femoris.
The glenoidal labrum.

Transverse acetabular.

The **articular capsule** (fig. 492) is strong and dense. Above, it is attached to the margin of the acetabulum, 5 or 6 mm. beyond the glenoidal labrum behind; in front, it is attached to the outer margin of the labrum, and, opposite the acetabular notch, it is connected to the transverse acetabular ligament

and the edge of the obturator foramen. It surrounds the neck of the femur, and is attached, in front, to the intertrochanteric line; above, to the base of the neck; behind, to the neck, about 1.25 cm. above the intertrochanteric crest; below, to the lower part of the neck close to the lesser trochanter. From its femoral attachment some of the fibres are reflected upwards along the neck as longitudinal bands, termed *retinacula*. The capsule is much thicker at the upper and fore part of the joint, where the greatest amount of resistance is required; behind and below, it is thin and loose. It consists of two sets of fibres, circular and longitudinal. The circular fibres (*zona orbicularis*) are most abundant at the lower and back part of the capsule (fig. 492), and form a sling

FIG. 493.—Right hip-joint from the front.



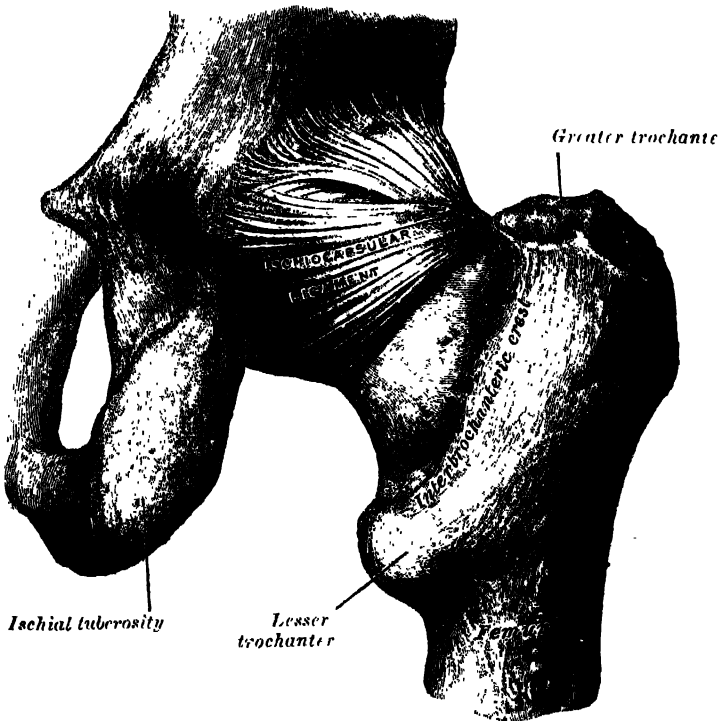
or collar around the neck of the femur. Anteriorly, they blend with the deep surface of the iliofemoral ligament, and gain an attachment to the anterior inferior iliac spine. The longitudinal fibres are greatest in amount at the upper and front part of the capsule, where they are reinforced by the *iliofemoral ligament*. The articular capsule is also strengthened by the *pubocapsular* and the *ischiocapsular ligaments*. The external surface of the capsule is rough, covered by numerous muscles, and separated in front from the Psoas major and Iliacus by a bursa, which not infrequently communicates by a circular aperture with the cavity of the joint.

The *synovial stratum* is very extensive. Commencing at the margin of the cartilaginous surface of the head of the femur, it covers the portion of the neck which is contained within the joint; from the neck it is reflected on the internal surface of the fibrous stratum of the capsule, covers both surfaces of the glenoidal labrum, ensheathes the ligamentum teres as far as the head of the femur, and covers the mass of fat contained in the bottom of the acetabulum. The joint cavity sometimes communicates, through a hole in the capsule between the vertical band of the iliofemoral ligament and the pubo-

capsular ligament, with a bursa situated on the deep surfaces of the Psoas major and Iliacus.

The iliofemoral ligament (fig. 493), triangular in shape and of great strength, lies in front of the joint and is intimately connected with the capsule. Its apex is attached to the lower part of the anterior inferior iliac spine, its base to the intertrochanteric line of the femur. The medial and lateral parts of the ligament are strong bands, while the central part is relatively thin and weak; the medial band is vertical in direction and is fixed to the lower part of the intertrochanteric line; the lateral band is oblique and is attached to the upper part of the same line. The iliofemoral ligament is frequently called the Y-shaped ligament of Bigelow, and its lateral band the *iliotrochanteric ligament*.

FIG. 494.—Right hip-joint from behind.



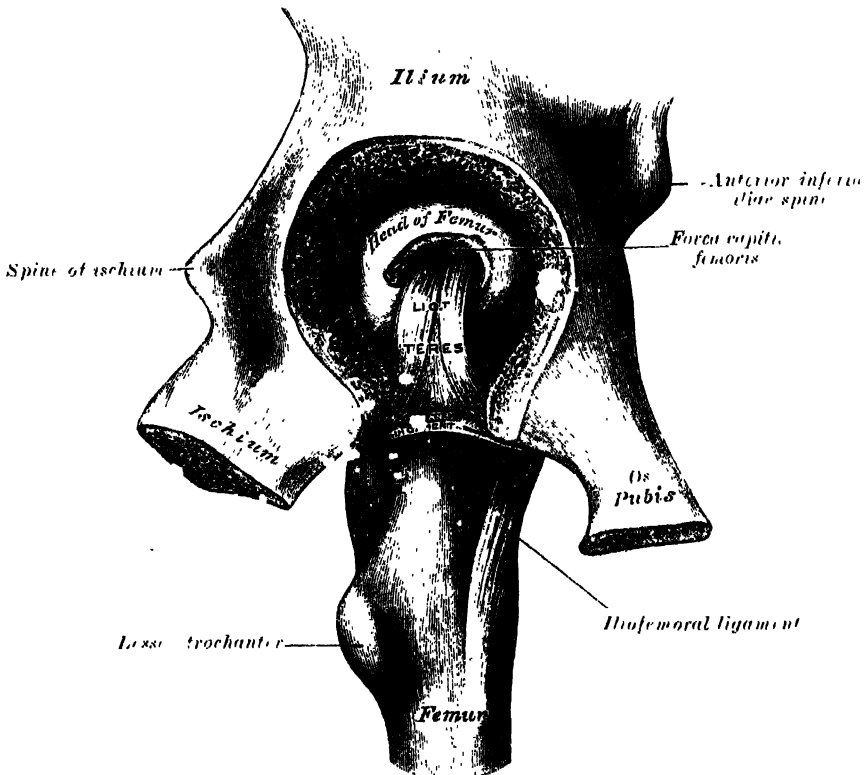
The pubocapsular ligament (fig. 493) is triangular in form with its base at the hip-bone, where it is attached to the iliopectineal eminence, the superior ramus of the os pubis, the obturator crest and obturator membrane; below, it blends with the capsule and with the deep surface of the medial band of the iliofemoral ligament.

The ischiofemoral ligament (fig. 494) has a somewhat spiral disposition on the back of the joint. From its attachment to the ischium below and behind the acetabulum, it is directed upwards and lateralwards over the back of the neck of the femur. Some of its fibres are continuous with those of the zona orbicularis, others are implanted on to the greater trochanter.

The ligamentum teres femoris (fig. 495) is a triangular, somewhat flattened band implanted by its apex on the anterosuperior part of the fovea capitis femoris; its base is attached by two bands, one into either side of the acetabular notch, and between these bony attachments it blends with the transverse ligament. It is ensheathed by the synovial stratum, and varies greatly in strength in different subjects; occasionally only the synovial stratum exists, and in rare cases even this is absent. The ligament is made tense when the thigh is semiflexed and the limb then adducted or rotated outwards; it is relaxed when the limb is abducted.

The **glenoidal labrum** (cotyloid ligament) is a fibrocartilaginous rim attached to the margin of the acetabulum, the cavity of which it deepens; at the same time it protects the edge of the bone, and fills up the inequalities of its surface. It bridges over the notch as the *transverse acetabular ligament*, and thus forms a complete circle, which closely surrounds the head of the femur and assists in holding it in its place. It is triangular on section, its base being attached to the margin of the acetabulum, while its opposite edge is free and sharp. Its surfaces are invested by the synovial stratum; the internal surface is inclined inwards so as to narrow the acetabulum, and embrace the cartilaginous surface of the head of the femur. It is much thicker above and behind than below and in front.

FIG. 495.—Left hip-joint, opened by removing the floor of the acetabulum from within the pelvis.



The **transverse acetabular ligament** is in reality a portion of the glenoidal labrum, though differing from it in having no cartilage-cells among its fibres. It consists of strong, flattened fibres, which cross the acetabular notch, and convert it into a foramen through which the nutrient vessels enter the joint.

The *muscles* in relation with the joint are, in front, the Psoas major and Iliacus, separated from the capsule by a bursa; above, the reflected head of the Rectus femoris and the insertion of Glutæus minimus, the latter being closely adherent to the capsule; medially, the Obturator externus and Pectineus; behind the Piriformis, Gemellus superior, tendon of Obturator internus, Gemellus inferior, tendon of Obturator externus, and Quadratus femoris (fig. 496).

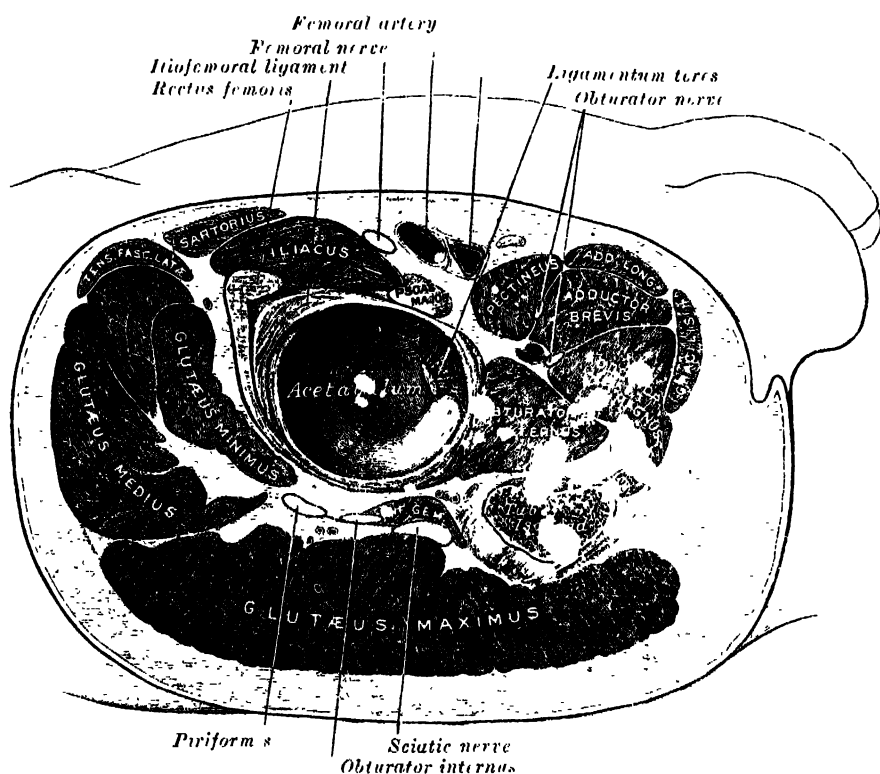
The *arteries* supplying the joint are derived from the obturator, medial femoral circumflex, and superior and inferior glutæal arteries.

The *nerves* are articular branches from the sacral plexus, sciatic, obturator, accessory obturator, and a filament from the branch of the femoral supplying the Rectus femoris.

Movements. --The movements of the hip-joint are very extensive, and consist of flexion, extension, adduction, abduction, circumduction, and rotation.

The length of the neck of the femur and its inclination to the body of the bone have the effect of converting the angular movements of flexion, extension, adduction, and abduction partially into rotatory movements in the joint. Thus when the thigh is flexed or extended, the head of the femur, on account of the *medial* inclination of the neck, rotates within the acetabulum with only a slight amount of gliding to and fro. The *forward* slope of the neck similarly affects the movements of adduction and abduction. Conversely rotation of the thigh, which is permitted by the *upward* inclination of the neck, is not a simple rotation of the head of the femur in the acetabulum, but is accompanied by a certain amount of gliding.

FIG. 496.--Structures surrounding right hip-joint.



The hip-joint presents a very striking contrast to the shoulder-joint in the much more complete mechanical arrangements for its security and for the limitation of its movements. In the shoulder, as has been seen, the head of the humerus is not adapted at all in size to the glenoid cavity, and is hardly restrained in any of its ordinary movements by the capsule. In the hip-joint, on the contrary, the head of the femur is closely fitted to the acetabulum for an area extending over nearly half a sphere, and at the margin of the bony cup it is still more closely embraced by the glenoidal labrum, so that the head of the femur is held in its place by that ligament even when the fibres of the capsule have been quite divided. The iliofemoral ligament is the strongest of all the ligaments in the body, and is put on the stretch by any attempt to extend the femur beyond a straight line with the trunk. That is to say, this ligament is the chief agent in maintaining the erect position without muscular fatigue; for a vertical line passing through the centre of gravity of the trunk falls behind the centres of rotation in the hip-joints, and therefore the pelvis tends to fall backwards, but is prevented by the tension of the iliofemoral ligaments. The security of the joint may be provided for also by the two bones being directly united through the ligamentum teres; but it is doubtful whether this ligament has much influence upon the mechanism of the joint. When the knee is flexed,

flexion of the hip-joint is arrested by the soft parts of the thigh and abdomen being brought into contact, and when the knee is extended, by the action of the hamstring muscles; extension is checked by the tension of the iliofemoral ligament; adduction by the thighs coming into contact; adduction with flexion by the lateral band of the iliofemoral ligament and the lateral part of the capsule; abduction by the medial band of the iliofemoral ligament and the pubocapsular ligament; rotation outwards by the lateral band of the iliofemoral ligament; and rotation inwards by the ischio-capsular ligament and the hinder part of the capsule. The muscles which *flex* the femur on the pelvis are the Psoas major, Iliacus, Rectus femoris, Sartorius, Pectineus, Adductores longus and brevis, and the anterior fibres of the Glutæi medius and minimus. *Extension* is mainly performed by the Glutæus maximus, assisted by the hamstring muscles and the ischial head of the Adductor magnus. The thigh is *adducted* by the Adductores magnus, longus, and brevis, the Pectineus, the Gracilis, and lower part of the Glutæus maximus, and *abducted* by the Glutæi medius and minimus, and the upper part of the Glutæus maximus. The muscles which *rotate* the thigh *inwards* are the Glutæus minimus and the anterior fibres of the Glutæus medius, the Tensor fasciæ latæ and the Iliacus and Psoas major; while those which rotate it *outwards* are the posterior fibres of the Glutæus medius, the Piriformis, Obturatores externus and internus, Gemelli superior and inferior, Quadratus femoris, Glutæus maximus, the Adductores longus, brevis, and magnus, the Pectineus, and the Sartorius.

Applied Anatomy.—In dislocation of the hip, 'the head of the thigh-bone may rest at any point around its socket' (Bryant); but whatever position it ultimately assumes, the primary displacement is generally downwards and medialwards, the capsule giving way at its weakest—that is, its lower and medial—part. The situation subsequently assumed by the head of the bone is determined by the degree of flexion or extension, and of outward or inward rotation of the thigh at the moment of dislocation, influenced, no doubt, by the iliofemoral ligament, which is not easily ruptured. When, for instance, the head of the bone is forced backwards, this ligament forms a fixed axis, round which the head of the bone rotates, and is driven on to the dorsum of the ilium. The iliofemoral ligament also influences the position of the thigh in the various dislocations: in the dislocations backwards it is tense, and produces inversion of the limb; in the dislocation on to the os pubis, it is relaxed, and therefore allows the external rotator muscles to evert the thigh; while in dislocation into the obturator foramen it is tense, and produces flexion. The muscles inserted into the upper part of the femur, with the exception of the Obturator internus, have very little direct influence in determining the position of the head of the bone. Bigelow, however, has endeavoured to show that the Obturator internus is the principal agent in deciding whether, in the backward dislocations, the head of the bone shall be ultimately lodged on the dorsum of the ilium, or in or near the greater sciatic notch; in both dislocations the head passes, in the first instance, in the same direction. But, as Bigelow asserts, in the displacement on to the dorsum the head of the bone travels up behind the acetabulum, in front of the muscle; while in the dislocation into the greater sciatic notch the head passes behind the muscle, and is prevented from reaching the dorsum, in consequence of the tendon of the muscle arching over the neck of the bone, and it therefore remains in the neighbourhood of the notch. Bigelow distinguishes these two forms of dislocation by describing them as dislocations backwards, 'above and below' the Obturator internus.

The iliofemoral ligament is rarely torn in dislocations of the hip, and this fact is taken advantage of by the surgeon in reducing these dislocations by manipulation. It is made to act as the fulcrum to a lever, of which the long arm is the body of the femur, and the short arm the neck of the bone (fig. 497).

The hip-joint is rarely the seat of acute synovitis from injury, on account of its deep position and its thick covering of soft parts. Acute inflammation may, and does, frequently occur as the result of bacterial infections, as in rheumatism, pyæmia, etc. When, in these cases, effusion takes place, and the joint is distended with fluid, the swelling is not very easy to detect on account of the thickness of the capsule and the depth of the articulation. It is principally to be found on the front of the joint, just medial to the iliofemoral ligament; or behind, at the lower and back part. In these two places the capsule is thinner than elsewhere. Disease of the hip-joint is much oftener of a chronic character, and is usually of tuberculous origin. It begins usually in the bone, and, in most cases, in the growing, highly vascular tissue in the neighbourhood of the epiphysal cartilage of the femoral head. In this respect it differs very materially from tuberculous arthritis of the knee, where the disease usually commences in the synovial stratum.

In chronic hip-disease the affected limb assumes an altered position, the cause of which it is important to understand. In the early stage of a typical case, the limb is flexed, abducted, and rotated outwards. In this position all the ligaments of the joint are relaxed: the front of the capsule by flexion; the lateral band of the iliofemoral ligament by abduction; and the medial band of this ligament and the back of the capsule

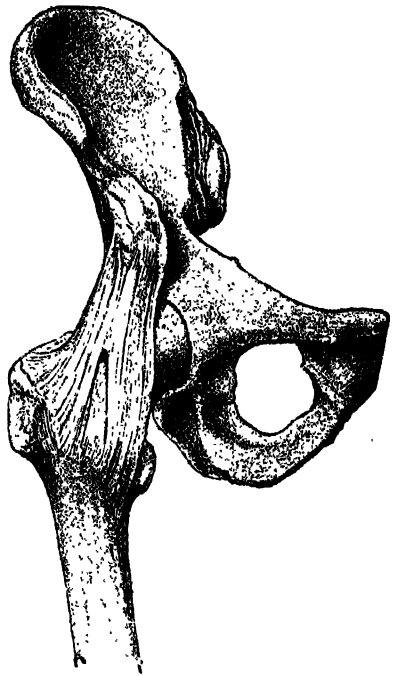
by rotation outwards. It is, therefore, the position of greatest ease. The condition is not quite obvious at first, upon examining a patient. If the patient be laid in the supine position, the affected limb will be found to be extended and parallel with the other. But it will be seen that the pelvis is tilted downwards on the diseased side and the limb apparently longer than its fellow, and that the lumbar portion of the vertebral column is arched forwards (lordosis). The condition is thus explained: a limb which is flexed and abducted is obviously useless for progression, and in order to overcome the difficulty the patient depresses the affected side of his pelvis, thus producing parallelism of his limbs, and at the same time rotates his pelvis on its transverse horizontal axis, so as to direct the limb downwards, instead of forwards. In the later stages of the disease the limb becomes flexed and adducted and inverted. This position probably depends upon muscular action, at all events as regards the adduction. The Adductor muscles are supplied by the obturator nerve, which also largely supplies the joint. These muscles are therefore thrown into reflex spasm by the irritation of the peripheral terminations of this nerve in the inflamed articulation.

Osteo-arthritis is common in the hip-joint, and more so in the male than in the female, in whom the knee-joint is more frequently affected. It is a disease of middle age or advanced life. When much deformity is associated with chronic osteo-arthritis the condition is spoken of as *arthritis deformans of the hip*, or *morbus coxæ senilis*. The head of the femur is worn away, and after it often the neck too, until a new irregular articular surface is produced, around which a new formation of bone occurs, and also about the edges of the acetabulum, which is widened and eroded by a similar chronic process. Pain in the joint, shortening of the limb, and great limitation of movement result, with much creaking and grating when the joint is moved.

Congenital dislocation is more commonly met with in the hip-joint than in any other articulation. The displacement usually takes place on to the dorsum ilii. It gives rise to extreme lordosis, and a waddling gait is noticed as soon as the child commences to walk.

Excision of the hip may be required for disease or for injury, especially gunshot. It may be performed either by an anterior or a posterior incision. The former entails less interference with important structures, especially muscles, than the latter, but permits of less efficient drainage. In the operation from the front an incision is made 8 to 10 cm. in length, starting immediately below and lateral to the anterior superior iliac spine, downwards between the Sartorius and Tensor fasciæ latæ. The interspace between the Gluteus minimus and Rectus femoris is then opened up, exposing the upper part of the capsule, which being incised discloses the neck of the bone. This can now be divided, and the head of the bone extracted. The posterior method consists in making an incision 8 to 10 cm. long, commencing midway between the top of the greater trochanter and the iliac crest, and extending down the posterior border of the trochanter. The muscles are detached from the greater trochanter, and the capsule opened freely. The head and neck are freed from the soft parts and as much affected bone removed as is thought necessary.

FIG. 497.—Hip-joint, showing the iliofemoral ligament. (After Bigelow.)

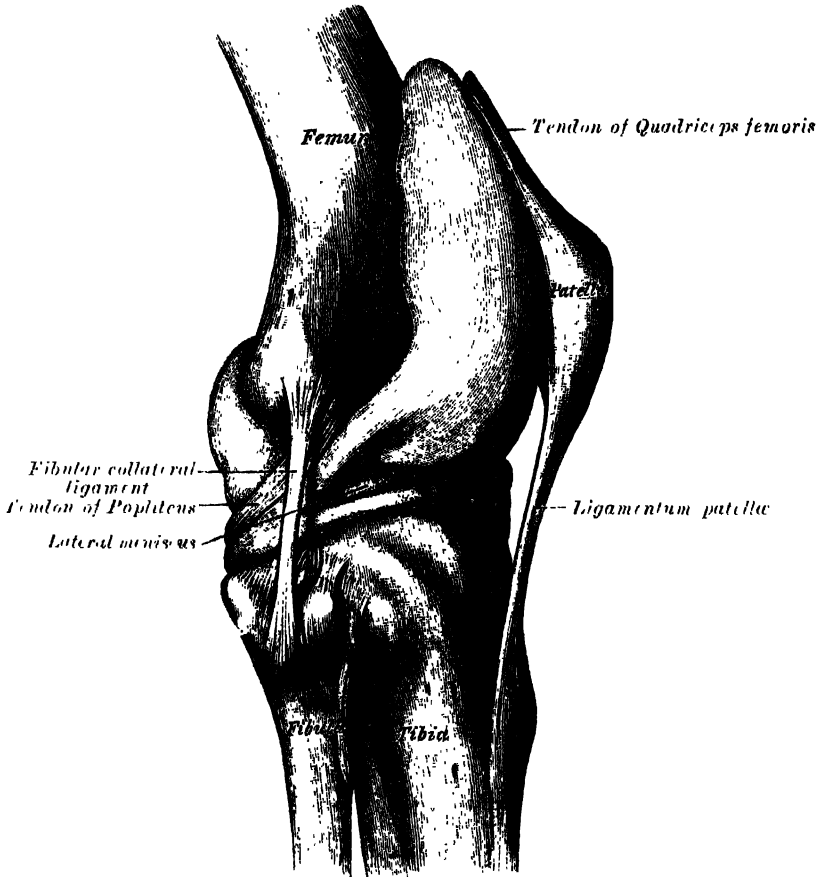


IV. KNEE-JOINT

The knee-joint was formerly described as a ginglymus or hinge-joint, but is really of a much more complicated character. It must be regarded as consisting of three articulations in one: two condyloid joints, one between either condyle of the femur and the corresponding meniscus and condyle of the tibia; and a third between the patella and the femur, partly arthrodial, but not completely so, since the articular surfaces are not mutually adapted to each other, so that the movement is not a simple gliding one. This view of the construction of the knee-joint receives confirmation from a study of the articulation in some of the lower mammals, where, corresponding to these three subdivisions,

three synovial cavities are sometimes found, either entirely distinct or or connected together by small communications. This view is further rendered probable by the existence in the middle of the joint of the two cruciate ligaments, which may be regarded as the collateral ligaments of the medial and lateral joints. The existence of the patellar fold of synovial membrane would

FIG. 498.—Articular capsule of right knee-joint (distended). Lateral aspect.



further indicate a tendency to separation of the synovial cavity into two minor sacs, one corresponding to the lateral and the other to the medial joint.

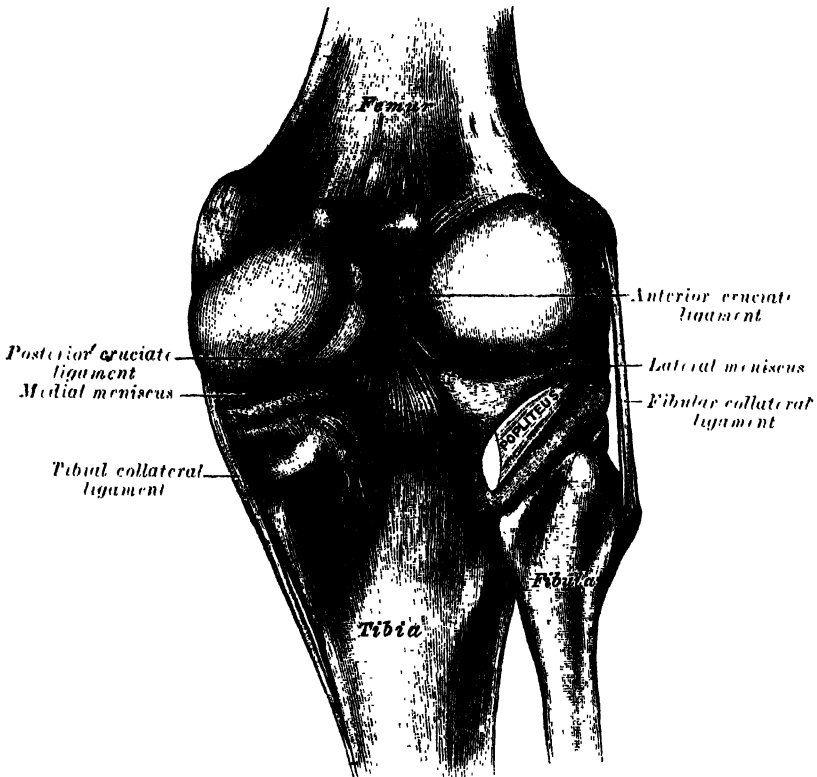
The ligaments of the joint are :

The articular capsule.	Anterior cruciate.
Ligamentum patellae.	Posterior cruciate.
Oblique popliteal.	Medial and lateral menisci.
Arcuate popliteal.	Transverse.
Tibial collateral.	Coronary.
Fibular collateral	

The **articular capsule** (figs. 498, 499) consists of a fibrous stratum which is strengthened in almost its entire extent by bands inseparably connected with it; above and in front, beneath the tendon of the Quadriceps femoris, it is represented only by the synovial stratum. Its chief strengthening bands are derived from the fascia lata and from the tendons surrounding the joint. In front, expansions from the Vasti and from the fascia lata and its iliotibial tract fill in the intervals between the anterior and collateral ligaments, constituting the *medial and lateral patellar retinacula*. Behind, the capsule consists of vertical fibres which arise from the condyles of the femur and tibia and from

the sides of the inter-condyloid fossa of the femur; the posterior part of the capsule is therefore situated on the sides, and in front, of the cruciate ligaments, which are thus excluded from the joint-cavity. Behind the cruciate ligaments is the oblique popliteal ligament which is augmented by fibres derived from the tendon of the Semimembranosus. Laterally, a prolongation from the iliotibial tract fills the interval between the oblique popliteal and the fibular collateral ligaments, and partly covers the latter. Medially, expansions from the Sartorius and Semimembranosus pass upwards to the tibial collateral ligament and strengthen the capsule.

FIG. 499.—Articular capsule of right knee-joint (distended). Posterior aspect.

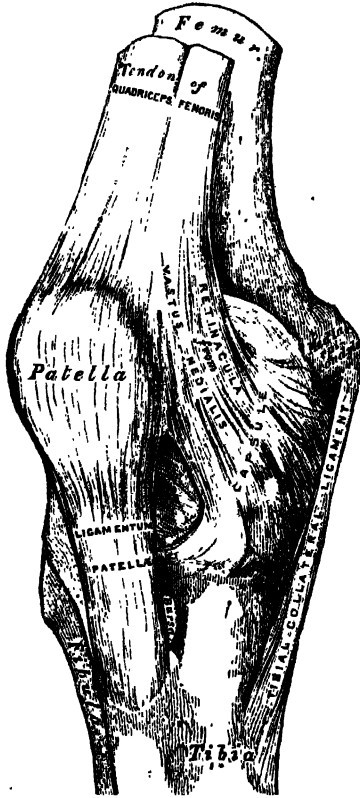


The **synovial stratum** of the knee-joint is the largest and most extensive in the body. Commencing at the upper border of the patella, it forms a large pouch beneath the Quadriceps femoris on the lower part of the front of the femur (figs. 498, 505), and usually communicates with a bursa interposed between the tendon and the front of the femur. The pouch between the Quadriceps and front of the femur is supported, during the movements of the knee, by a small muscle, the *Articularis genus*, which is inserted into it. On either side of the patella, the synovial stratum extends beneath the aponeuroses of the Vasti, and more especially beneath that of the Vastus medialis. Below the patella it is separated from the ligamentum patellæ by a considerable quantity of fat, known as the *infrapatellar pad*. From the medial and lateral borders of the articular surface of the patella, reduplications of the synovial stratum project into the interior of the joint. These form two fringe-like folds termed the *alar folds*; below, these folds converge and are continued as a single band, the *patellar fold* (*ligamentum mucosum*), to the front of the intercondyloid fossa of the femur. On either side of the joint, the synovial stratum passes downwards from the femur, lining the fibrous stratum of the capsule as far as its attachment to the menisci; it may then be traced over the upper

surfaces of these to their free borders, and thence along their under surfaces to the tibia. At the back part of the lateral meniscus it forms a cul-de-sac between the groove on its surface and the tendon of the Popliteus; it is reflected across the front of the cruciate ligaments, which are therefore situated outside the synovial cavity.

The *ligamentum patellæ* (fig. 500) is the central portion of the common tendon of the Quadriceps femoris, which is continued from the patella to the tuberosity of the tibia. It is a strong, flat, ligamentous band, about 8 cm. in length, attached, above, to the apex and adjoining margins and to the rough depression on the posterior surface of the patella; and below, to the tuberosity

FIG. 500.—Right knee-joint.
Anteromedial view.



of the tibia; its superficial fibres are continuous over the front of the patella with those of the tendon of the Quadriceps femoris. The medial and lateral portions of the tendon of the Quadriceps pass down on either side of the patella, to be inserted into the upper extremity of the tibia on either side of the tuberosity; these portions merge into the capsule, as stated above, forming the medial and lateral patellar retinacula. The posterior surface of the ligamentum patellæ is separated from the synovial stratum of the articular capsule by a large infrapatellar pad of fat, and from the tibia by a bursa.

The oblique popliteal ligament (posterior ligament) (fig. 501) is a broad, flat, fibrous band, formed of fasciculi separated from one another by apertures for the passage of vessels and nerves. It is attached above to the upper margin of the intercondyloid fossa and lateral condyle of the femur, and below it shades off into the capsule. Superficially there is a strong fasciculus derived from the tendon of the Semimembranosus; it passes from the posterior part of the medial condyle of the tibia obliquely upwards and lateralwards to the posterior part of the lateral condyle of the femur. The oblique popliteal ligament forms part of the floor of the popliteal fossa, and the popliteal artery rests upon it.

The arcuate popliteal ligament (fig. 501) is an arched bundle of fibres

which varies somewhat in strength and appearance. It is attached to the lateral condyle of the femur and passes downwards to fuse with the capsule below the oblique popliteal ligament. Two bands, an anterior and a posterior, converge from the upper and lower extremities of the arcuate popliteal ligament; they unite below to form the *retinaculum* of the ligament, which is fixed to the apex of the head of the fibula. The anterior band of this retinaculum is sometimes described as the *short fibular collateral ligament*.

The tibial collateral ligament (internal lateral ligament) (figs. 500, 501) is a broad, flat band, situated nearer to the back than to the front of the joint. It is attached, above, to the medial epicondyle of the femur immediately below the adductor tubercle; below, to the medial condyle and medial surface of the body of the tibia. The fibres of the posterior part of the ligament are short and incline backwards as they descend; they are inserted into the tibia above the groove for the Semimembranosus. The anterior part of the ligament, about 10 cm. long, inclines forwards as it descends; it is inserted into the medial surface of the body of the tibia about 2.5 cm. below the level of the condyle. It is crossed, at its lower part, by the tendons of the Sartorius Gracilis, and Semitendinosus, a bursa being interposed. Its deep surface covers

the inferior medial genicular vessels and nerve and the anterior portion of the tendon of the Semimembranosus, with which it is connected by a few fibres ; it is intimately adherent to the medial meniscus.

The **fibular collateral ligament** (external lateral ligament) (fig. 503) is a strong, rounded cord, attached, above, to the lateral epicondyle of the femur, immediately above the groove for the tendon of the Popliteus ; below, to the lateral side of the head of the fibula, in front of the styloid process. The greater part of its lateral surface is covered by the tendon of the Biceps femoris ; the tendon, however, divides at its insertion into two parts, which are separated

FIG. 501.—Right knee-joint
Posterior view.

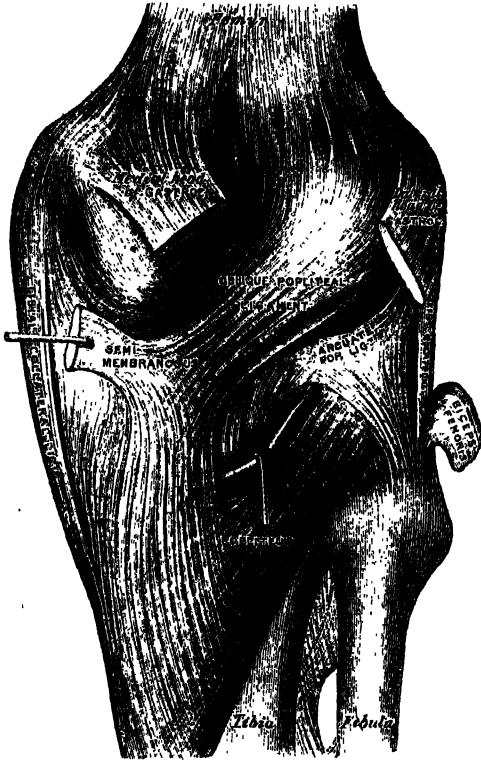
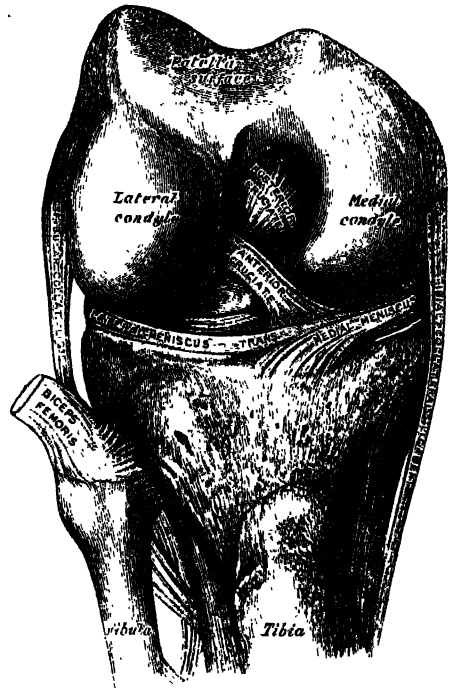


FIG. 502.—Right knee-joint, dissected
from the front.



by the ligament. Deep to the ligament are the tendon of the Popliteus, and the inferior lateral genicular vessels and nerve. The ligament has no attachment to the lateral meniscus.

The **cruciate ligaments** are of considerable strength, and are situated in the middle of the joint, nearer to its posterior than to its anterior surface. They are called *cruciate* because they cross each other somewhat like the lines of the letter X ; and have received the names *anterior* and *posterior*, from the position of their attachments to the tibia.

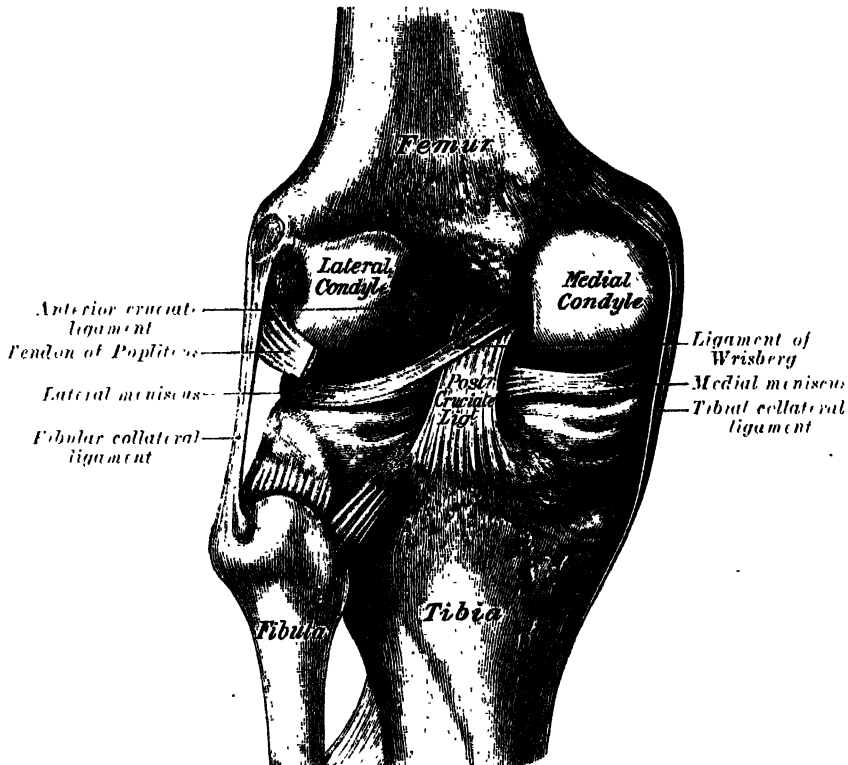
The **anterior cruciate ligament** (fig. 502) is attached to the depression in front of the intercondyloid eminence of the tibia, being blended with the anterior extremity of the lateral meniscus ; it passes upwards, backwards, and lateralwards, and is fixed into the medial and back part of the lateral condyle of the femur.

The **posterior cruciate ligament** (fig. 503) is stronger, but shorter and less oblique in its direction, than the anterior. It is attached to the posterior intercondyloid fossa of the tibia, and to the posterior extremity of the lateral meniscus ; it passes upwards, forwards, and medialwards, to be fixed into the lateral and front part of the medial condyle of the femur.

The **menisci** (semilunar fibrocartilages) (fig. 504) are two crescentic lamellæ, which serve to deepen the surfaces of the head of the tibia for articulation with the condyles of the femur. The peripheral border of each meniscus is thick, convex, and attached to the inside of the articular capsule; the opposite border is thin, concave, and free. The upper surfaces of the menisci are concave, and in contact with the condyles of the femur; their lower surfaces are flat, and rest upon the head of the tibia; both surfaces are smooth, and enveloped by the synovial stratum. Each meniscus covers approximately the peripheral two-thirds of the corresponding articular surface of the tibia.

The **medial meniscus** is nearly semicircular in form, a little elongated from before backwards, and broader behind than in front; its anterior end is attached to the anterior intercondyloid fossa of the tibia, in front of the anterior cruciate

FIG. 503.—Left knee-joint, dissected from behind.



ligament, some of its fibres being continued, as the transverse ligament, to the anterior margin of the lateral meniscus; its posterior end is fixed to the posterior intercondyloid fossa of the tibia, between the attachments of the lateral meniscus and the posterior cruciate ligament.

The **lateral meniscus** is nearly circular and covers a larger portion of the articular surface than the medial meniscus. It is grooved posteriorly for the tendon of the Popliteus, which separates it from the fibular collateral ligament. Its anterior end is attached in front of the intercondyloid eminence of the tibia, behind and lateral to the anterior cruciate ligament, with which it blends; the posterior end is attached behind the intercondyloid eminence of the tibia and in front of the posterior end of the medial meniscus. The anterior attachment of the lateral meniscus is twisted on itself so that its free margin looks backwards and upwards, its anterior end resting on a sloping shelf of bone on the front of the lateral process of the intercondyloid eminence. Close to its posterior attachment it sends off a strong fasciculus, the *ligament of Wrisberg* (figs. 503, 504), which passes upwards and medialwards, to be inserted into the medial condyle of the femur, immediately behind the attachment of the posterior

cruciate ligament. Occasionally a small fasciculus passes forwards to be inserted into the lateral part of the anterior cruciate ligament. The lateral meniscus gives off from its anterior convex margin a fasciculus which forms the transverse ligament.

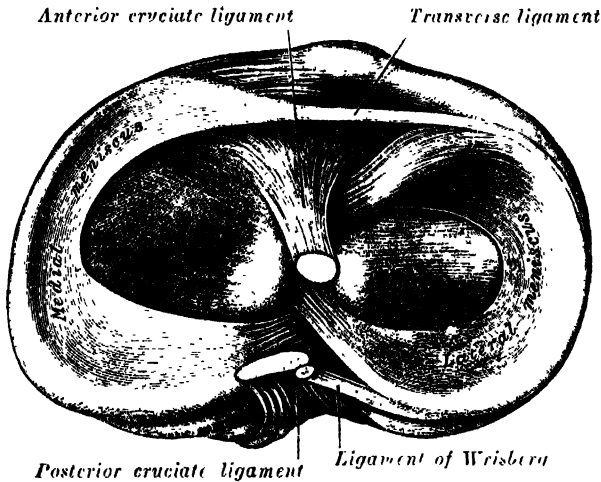
The **transverse ligament** (fig. 504) connects the anterior convex margin of the lateral meniscus to the anterior end of the medial meniscus; its thickness varies considerably in different subjects, and it is sometimes absent.

The **coronary ligaments** are merely portions of the capsule, connecting the periphery of either meniscus with the margin of the head of the tibia.

Bursæ.—The bursæ near the knee-joint are the following:

In front there are four bursæ: a large one is interposed between the lower part of the patella and the skin, a small one between the upper part of the tibia and the ligamentum patellæ, a third between the lower part of the tuberosity of the tibia and the skin, and a fourth between the anterior surface of the lower part of the femur and the deep surface of the Quadriceps femoris which usually

FIG. 504.—Head of right tibia seen from above, showing menisci and attachments of ligaments.



communicates with the knee-joint (fig. 505). Laterally there are four bursæ: (1) one (which sometimes communicates with the joint) between the lateral head of the Gastrocnemius and the capsule; (2) one between the fibular collateral ligament and the tendon of the Biceps femoris; (3) one between the fibular collateral ligament and the tendon of the Popliteus (this is sometimes only an expansion from the next bursa); (4) one between the tendon of the Popliteus and the lateral condyle of the femur, usually an extension from the synovial stratum of the joint. Medially, there are five bursæ: (1) one between the medial head of the Gastrocnemius and the capsule: this sends a prolongation between the tendon of the medial head of the Gastrocnemius and the tendon of the Semimembranosus and often communicates with the joint; (2) one superficial to the tibial collateral ligament, between it and the tendons of the Sartorius, Gracilis, and Semitendinosus; (3) one deep to the tibial collateral ligament, between it and the tendon of the Semimembranosus (this is sometimes only an expansion from the next bursa); (4) one between the tendon of the Semimembranosus and the head of the tibia; (5) occasionally there is a bursa between the tendons of the Semimembranosus and Semitendinosus.

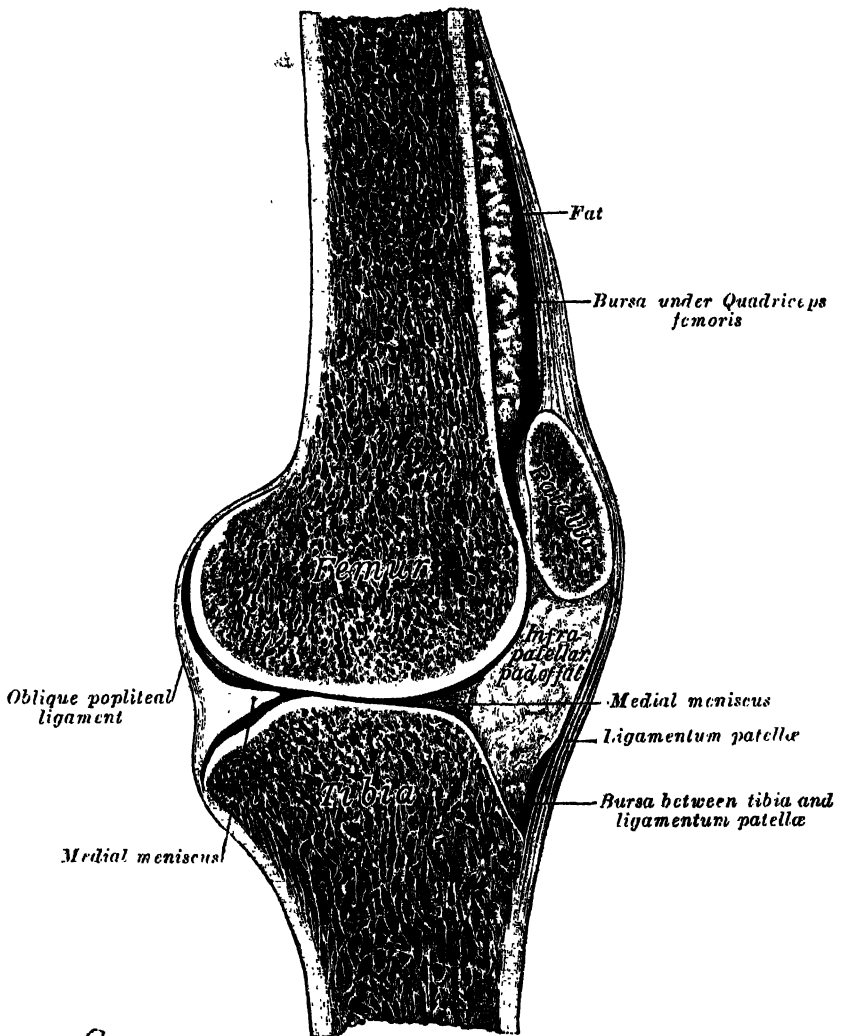
Structures around the joint.—In front, and at the sides, is the Quadriceps femoris; laterally, the tendons of the Biceps femoris and Popliteus and the common peroneal nerve; medially, the Sartorius, Gracilis, Semitendinosus, and Semimembranosus; behind, the popliteal vessels, and the tibial nerve, Popliteus, Plantaris, and medial and lateral heads of the Gastrocnemius, some lymph-glands, and fat.

The *arteries* supplying the joint are the highest genicular (*anastomotica magna*), a branch of the femoral, the genicular branches of the popliteal, the recurrent branches of the anterior tibial, and the descending branch from the lateral femoral circumflex of the *arteria profunda femoris*.

The *nerves* are derived from the obturator, femoral, tibial, and common peroneal.

Movements.—The movements which take place at the knee-joint are flexion and extension, and, in certain positions of the joint, internal and external rotation. The movements of flexion and extension at this joint differ from those in a typical

FIG. 505.—Sagittal section of right knee-joint.



hinge-joint, such as the elbow, in that (a) the axis round which motion takes place is not a fixed one, but shifts forwards during extension and backwards during flexion; (b) the commencement of flexion and the end of extension are accompanied by rotatory movements associated with the fixation of the limb in a position of great stability. The movement from full flexion to full extension may therefore be described in three phases:

1. In the fully flexed condition the posterior parts of the femoral condyles rest on the corresponding portions of the meniscotibial surfaces, and in this position a slight amount of simple rolling movement is allowed.

2. During the passage of the limb from the flexed to the extended position a gliding movement is superposed on the rolling, so that the axis, which at the com-

ment is represented by a line through the medial and lateral condyles of the femur, gradually shifts forwards. In this part of the movement, the posterior two-thirds of the tibial articular surfaces of the two femoral condyles are involved, and as these have similar curvatures and are parallel to one another, they move forwards equally.

3. The lateral condyle of the femur is brought almost to rest by the tightening of the anterior cruciate ligament; it moves, however, slightly forwards and medialwards, pushing before it the anterior part of the lateral meniscus. The tibial surface on the medial condyle is prolonged farther forwards than that on the lateral, and this prolongation is directed lateralwards. When, therefore, the movement forwards of the condyles is checked by the anterior cruciate ligament, continued muscular action causes the medial condyle, dragging with it the meniscus, to travel backwards and medialwards, thus producing an internal rotation of the thigh on the leg. When the position of full extension is reached the lateral part of the groove on the lateral condyle is pressed against the anterior part of the corresponding meniscus, while the medial part of the groove rests on the articular margin in front of the lateral process of the tibial intercondyloid eminence. Into the groove on the medial condyle is fitted the anterior part of the medial meniscus, while the anterior cruciate ligament and the articular margin in front of the medial process of the tibial intercondyloid eminence are received into the fore part of the intercondyloid fossa of the femur. This third phase, by which all these parts are brought into accurate apposition, is known as the 'screwing home,' or locking movement of the joint.

The complete movement of flexion is the converse of that described above, and is therefore preceded by an external rotation of the femur which unlocks the extended joint.

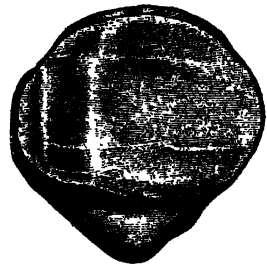
The axes round which the movements of flexion and extension take place are not precisely at right angles to either bone; in flexion, the femur and tibia are in the same plane, but in extension the one bone forms an angle, opening lateralwards, with the other.

In addition to the rotatory movements associated with the completion of extension and the initiation of flexion, rotation inwards or outwards can be effected when the joint is partially flexed; these movements take place mainly between the tibia and the menisci, and are freest when the leg is bent at right angles with the thigh.

Movements of the patella.—The articular surface of the patella is indistinctly divided into seven facets—upper, middle, and lower horizontal pairs, and a medial perpendicular facet (fig. 506). When the knee is forcibly flexed, the medial perpendicular facet is in contact with the semilunar surface on the lateral part of the medial condyle; this semilunar surface is a prolongation backwards of the medial part of the patellar surface. As the leg is carried from the flexed to the extended position, first the highest pair, then the middle pair, and lastly the lowest pair of horizontal facets is successively brought into contact with the patellar surface of the femur. In the extended position, when the Quadriceps femoris is relaxed, the patella lies loosely on the front of the lower end of the femur.

During flexion, the ligamentum patellæ is stretched, and in extreme flexion the posterior cruciate ligament, the oblique popliteal and collateral ligaments and, to a slight extent, the anterior cruciate ligament, are relaxed. Flexion is checked during life by the contact of the leg with the thigh. When the knee joint is fully extended the oblique popliteal and collateral ligaments, the anterior cruciate ligament, and the posterior cruciate ligament, are rendered tense; in the act of extending the knee, the ligamentum patellæ is tightened by the Quadriceps femoris, but in full extension with the heel supported it is relaxed. Rotation inwards is checked by the anterior cruciate ligament; rotation outwards tends to uncross and relax the cruciate ligaments, but is checked by the tibial collateral ligament. The main function of the cruciate ligaments is to act as a direct bond between the tibia and femur and to prevent the former bone from being carried too far backwards or forwards. They also assist the collateral ligaments in resisting any bending of the

FIG. 506.—Posterior surface of the right patella, showing diagrammatically the areas of contact with the femur in different positions of the knee.



joint to either side. The menisci adapt the surfaces of the tibia to the shape of the femoral condyles to a certain extent, and so fill up the intervals which would otherwise be left in the varying positions of the joint, and permit of the two varieties of motion, flexion (and extension), and rotation, as explained above. The patella is a great defence to the front of the knee-joint, and distributes upon a large and tolerably even surface, during kneeling, the pressure which would otherwise fall upon the prominent ridges of the condyles; it also affords leverage to the Quadriceps femoris.

When standing erect in the attitude of 'attention,' the weight of the body falls in front of a line carried across the centres of the knee-joints, and therefore tends to produce over-extension of the articulation; this, however, is prevented by the tension of the anterior cruciate, oblique popliteal, and collateral ligaments.

Extension of the leg on the thigh is performed by the Quadriceps femoris; *flexion* by the Biceps femoris, Semitendinosus, and Semimembranosus, assisted by the Gracilis, Sartorius, Gastrocnemius, Popliteus, and Plantaris. *Rotation outwards* is effected by the Biceps femoris, and *rotation inwards* by the Popliteus, Semitendinosus, and, to a slight extent, by the Semimembranosus, the Sartorius, and the Gracilis. The Popliteus comes into action especially at the commencement of the movement of flexion of the knee; by its contraction, the leg is rotated inwards, or, if the tibia be fixed, the thigh is rotated outwards, and the knee-joint is unlocked.

Applied Anatomy.—From a consideration of the construction of the knee-joint, it would at first sight appear to be one of the least secure joints in the body. It is formed between the two longest bones, and therefore the amount of leverage which can be brought to bear upon it is considerable; the articular surfaces are but ill-adapted to each other, and the range of motion which it enjoys is great. All these circumstances tend to render the articulation insecure; nevertheless, on account of the powerful ligaments which bind the bones together, the joint is one of the strongest in the body, and dislocation from traumatism is a rare occurrence. When, on the other hand, the ligaments have been softened or destroyed by disease, partial displacement is liable to occur, and is frequently brought about by the action of the muscles.

One or other of the menisci may become displaced and nipped between the femur and tibia. The accident is produced by a twist of the leg when the knee is flexed, and is accompanied by a sudden pain and fixation of the knee in a flexed position. The meniscus may be displaced either towards the tibial intercondyloid eminence, so that the cartilage becomes lodged in the intercondyloid fossa, or to one side, so that the cartilage projects beyond the margin of the two articular surfaces. The medial meniscus is much more commonly affected than the lateral.

Acute synovitis, the result of traumatism, is of frequent occurrence in the knee, on account of the superficial position of the joint. When the cavity is distended with fluid, the swelling shows itself above and at the sides of the patella, reaching about 2.5 cm., occasionally 5 cm. or more, above the patellar surface of the femur, and extending a little higher under the Vastus medialis than under the Vastus lateralis. The lower level of the synovial stratum is just at the level of the head of the tibia. Chronic synovitis shows itself principally in the form of pulpy degeneration of the synovial stratum, the result of tuberculous infection. Syphilitic disease with gummatous infiltration of the synovial stratum may take place. The knee is one of the joints most commonly affected with osteo-arthritis, and is more frequently the seat of this disease in women than in men. The occurrence of the so-called loose cartilages is almost confined to the knee, though they are occasionally met with in other joints. Many of them occur in cases of osteo-arthritis in which calcareous or cartilaginous material is formed in one of the synovial fringes and constitutes the foreign body, and may or may not become detached, in the former case only meriting the usual term, 'loose' cartilage. In other cases they have their origin in the exudation of inflammatory lymph, and possibly, in some rare instances, a portion of the articular cartilages or one of the menisci becomes detached and constitutes the foreign body.

In inflammatory affections of the knee-joint, the position of greatest ease, and therefore the one which is always assumed, is that of slight flexion. In this position there is the most complete relaxation of ligamentous structures, and, therefore, the greatest diminution in the tension caused by the effusion. If this flexed position be maintained for any length of time, it becomes permanent from fibrous adhesions taking place, and the utility of the limb is materially impaired. Attention should therefore be paid by the surgeon to the position of the limb, and by carefully applied splints, with the leg in an extended position, this untoward result should be prevented. In cases of septic synovitis, incisions to evacuate the pus should be made vertically on either side of the patella, between it and the condyles of the femur.

Genu valgum, or knock-knee, is a common deformity of childhood. In this condition, as the patient stands, the medial condyles of the two femora are in contact, but the medial malleoli of the tibiae are more or less widely separated from each other. When,

however, the knees are flexed to a right angle, the two legs are practically parallel with each other. If the deformity be marked, an osteotomy of the femur is required to correct it.

Excision of the knee-joint is most frequently required for tuberculous disease of this articulation, but is also practised in cases of disorganisation of the knee from other causes and occasionally for injury, gunshot or otherwise. The operation is best performed by a horseshoe-shaped incision, starting from one femoral condyle, descending as low as the tuberosity of the tibia, and then carried upwards to the other femoral condyle. The bone ends having been cleared, and in those cases where the operation is performed for tuberculous disease all pulpy tissue having been carefully removed, the section of the femur is first made. This should never include, in children, more than, at the most, two-thirds of the articular surface, otherwise the epiphysal cartilage will be involved, with disastrous results as regards the growth of the limb. Afterwards a thin slice, not more than 1.25 cm., should be removed from the upper end of the tibia. If any diseased tissue appears still to be left in the bones, it should be removed with the gouge, rather than by a further section.

The bursa about the knee-joint are sometimes the seat of enlargement. The bursa between the front of the patella and the skin is frequently affected in individuals who are in the habit of constantly kneeling, and the condition is then known as 'housemaid's knee.' The bursa beneath the Semimembranosus tendon also occasionally becomes enlarged, and forms a fluctuating swelling at the back of the knee. During extension, the swelling is firm and tense; but during flexion it becomes soft, and, as the bursa often communicates with the synovial cavity of the joint, the fluid it contains can be made to disappear by pressure when the knee is flexed. Extension of septic processes within the joint is apt to occur along the tendon-sheath of the Popliteus, and this may lead to deep-seated suppuration in the popliteal fossa, often associated with septic thrombosis of the popliteal vein: when this occurs amputation of the limb is necessary.

V. ARTICULATIONS BETWEEN THE TIBIA AND FIBULA

The articulations between the tibia and fibula are effected by ligaments which connect the extremities and bodies of the bones. The ligaments may consequently be subdivided into three sets: (1) those of the proximal tibiofibular articulation; (2) the crural interosseous membrane; (3) those of the distal tibiofibular articulation (tibiofibular syndesmosis).

1. PROXIMAL TIBIOFIBULAR ARTICULATION (fig. 502)

This articulation is an arthrodial joint between the lateral condyle of the tibia and the head of the fibula. The contiguous surfaces of the bones present flat, oval facets covered with cartilage and connected together by an articular capsule and by anterior and posterior ligaments.

The **articular capsule** envelops the articulation, being attached round the margins of the articular facets on the tibia and fibula: it is much thicker in front than behind. Occasionally the synovial stratum of the capsule is continuous with that of the knee-joint.

The **anterior ligament** of the head of the fibula consists of two or three flat bands, which pass obliquely upwards from the front of the head of the fibula to the front of the lateral condyle of the tibia.

The **posterior ligament** of the head of the fibula is a thick band, which passes obliquely upwards from the back of the head of the fibula to the back of the lateral condyle of the tibia. It is covered by the tendon of the Popliteus.

2. CRURAL INTEROSSEOUS MEMBRANE

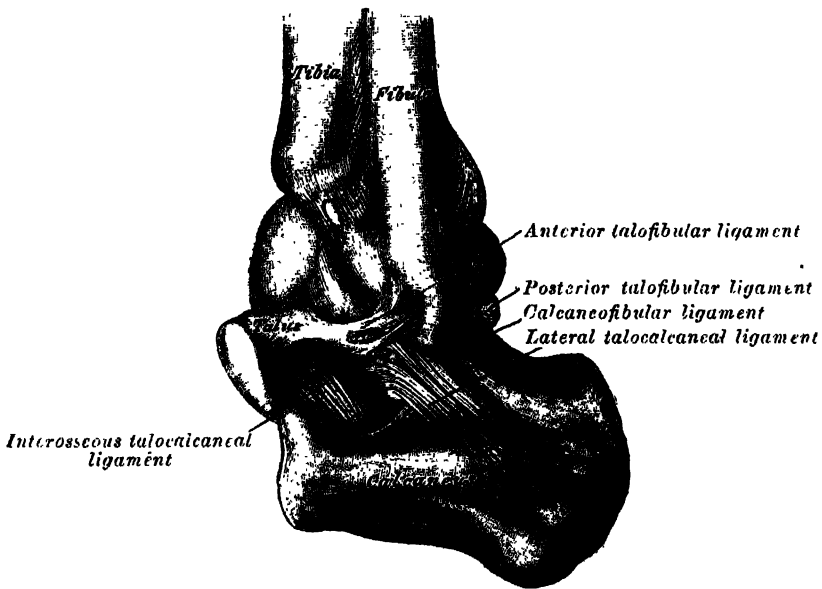
The **crural interosseous membrane** connects the interosseous crests of the tibia and fibula, and separates the muscles on the front from those on the back of the leg. It consists of oblique fibres, which for the most part run downwards and lateralwards; a few, however, pass in the opposite direction. The anterior tibial vessels pass above its upper margin; in its lower part is an opening for the passage of the anterior peroneal vessels. It is continuous below with the interosseous ligament of the tibiofibular syndesmosis, and presents numerous perforations for the passage of small vessels. It is in

relation, in front, with the *Tibialis anterior*, *Extensor digitorum longus*, *Extensor hallucis longus*, *Peronæus tertius*, and the anterior tibial vessels and deep peronæal nerve; behind, with the *Tibialis posterior* and *Flexor hallucis longus*.

3. DISTAL TIBIOFIBULAR ARTICULATION (TIBIOFIBULAR SYNDESMOSIS)

This syndesmosis is formed by the rough, convex surface of the medial side of the lower end of the fibula, and a rough concave surface, the fibular notch, on the lateral side of the tibia. Below, to the extent of about 4 mm., these surfaces are smooth, and covered with cartilage, continuous with that of the ankle-joint. The ligaments are: anterior, posterior, inferior transverse, and interosseous.

FIG. 507.—Articular capsule of left talocrural articulation (distended).
Lateral aspect.



The **anterior ligament** of the lateral malleolus (fig. 510) is a triangular band, broader below than above, which extends obliquely downwards and lateralwards between the adjacent margins of the tibia and fibula, on the front of the syndesmosis.

The **posterior ligament** of the lateral malleolus (fig. 508), smaller than the preceding, is disposed in a similar manner on the posterior surface of the syndesmosis. Its deep portion forms the **inferior transverse ligament**, a strong, thick band of yellowish fibres which passes transversely across the back of the joint, from the lateral malleolus to the posterior border of the articular surface of the tibia, almost as far as its malleolar process. The inferior transverse ligament projects below the margins of the bones, and forms part of the articulating surface for the talus.

The **interosseous ligament** is continuous, above, with the interosseous membrane and consists of numerous short, strong bands, which pass between the adjacent rough surfaces of the tibia and fibula, and constitute the chief bond of union between the bones.

The **synovial stratum** associated with the small arthrodial part of this joint is continuous with that of the ankle-joint.

VI. TALOCRURAL ARTICULATION OR ANKLE-JOINT

The ankle-joint is a ginglymus, or hinge-joint. Entering into its formation are the lower end of the tibia and its malleolus, the malleolus of the fibula, and the inferior transverse tibiofibular ligament, which together form a mortise for the reception of the trochlea of the talus. The bones are connected by the following ligaments :

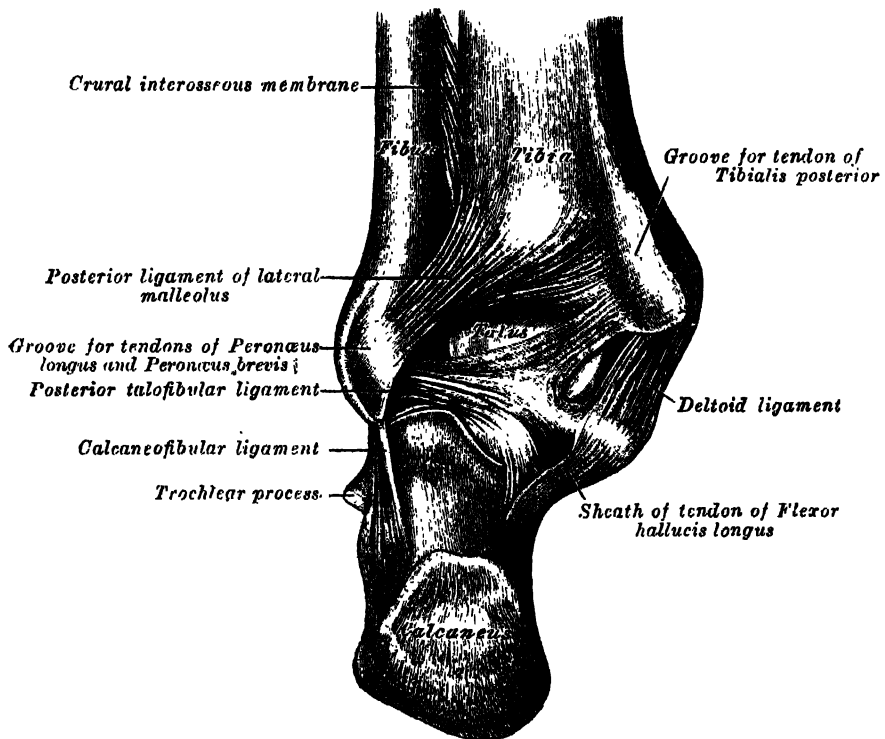
The articular capsule.
Deltoid.

Anterior talofibular.
Posterior talofibular.

Calcaneofibular.

The articular capsule (fig. 507) surrounds the joint, and its fibrous stratum is attached, above, to the borders of the articular surfaces of the tibia

FIG. 508.—Left talocrural articulation, from behind.



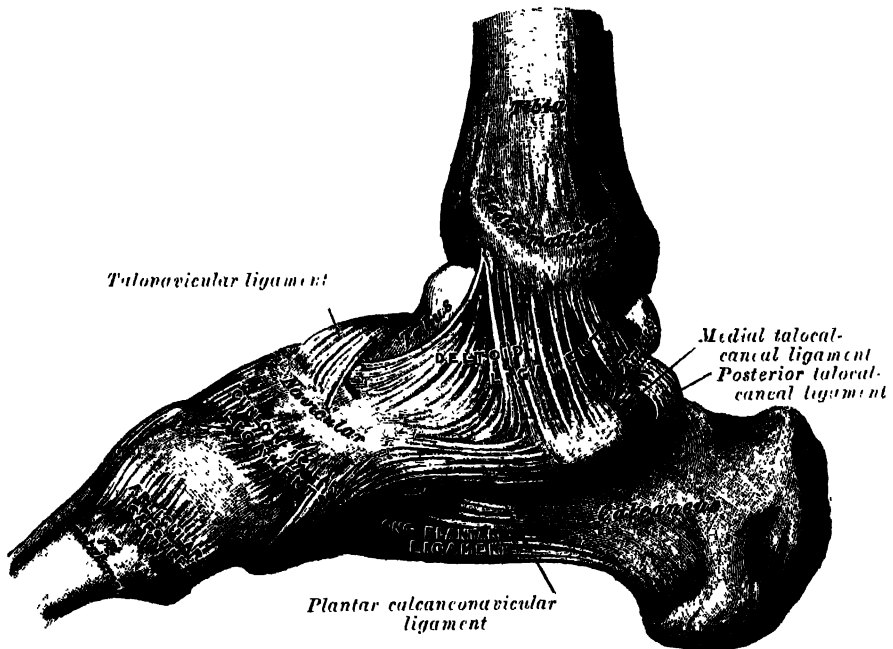
and malleoli, and below, to the talus around its trochlear articular surface. Its anterior part, often termed the *anterior ligament*, is a broad, thin, membranous layer, attached, above, to the anterior margin of the lower end of the tibia, and below, to the talus, in front of its superior articular surface. It is in relation, in front, with the extensor tendons of the toes, the tendons of the Tibialis anterior and Peronæus tertius, and the anterior tibial vessels and deep peronæal nerve. Its posterior part, often termed the *posterior ligament*, is very thin, and consists principally of transverse fibres. It is attached, above, to the margin of the articular surface of the tibia, blending with the inferior transverse ligament, and below, to the talus behind its superior articular facet. Laterally, it is somewhat thickened, and is attached to the hollow on the medial surface of the lateral malleolus.

The fibrous stratum is lined by a synovial stratum, and the joint-cavity is continued upwards for a short distance between the tibia and fibula.

The *deltoid ligament* (internal lateral ligament) (figs. 508, 509) is a strong, triangular band, attached, above, to the apex and anterior and posterior borders of the medial malleolus. It consists of two sets of fibres, superficial and deep,

Of the superficial fibres the anterior (*tibionavicular*) pass forwards to be attached to the tuberosity of the navicular bone, and immediately behind this they blend with the medial margin of the plantar calcaneonavicular ligament; the middle (*calcaneotibial*) descend almost perpendicularly and are fixed into the whole length of the sustentaculum tali of the calcaneus; the posterior fibres (*posterior talotibial*) pass backwards and lateralwards to be attached to the medial side of the talus, and to the prominent tubercle on its posterior surface, medially to the groove for the tendon of the Flexor hallucis longus. The deep fibres (*anterior talotibial*) are fixed, above, to the tip of the medial malleolus, and, below, to the medial surface of the talus. The deltoid ligament is crossed by the tendons of the Tibialis posterior and Flexor digitorum longus.

FIG. 509.—Ligaments of ankle and tarsus. Medial aspect.



The **anterior talofibular ligament** (fig. 510) passes from the anterior margin of the fibular malleolus, forwards and medialwards, to the talus, in front of its lateral articular facet.

The **posterior talofibular ligament** (fig. 508), strong and deeply seated, runs almost horizontally from the depression at the medial and posterior part of the fibular malleolus to the posterior process of the talus.

The **calcaneofibular ligament** (fig. 510) is a long rounded cord, running from the apex of the fibular malleolus downwards and slightly backwards to a tubercle on the lateral surface of the calcaneus. It is covered by the tendons of the Peronæi longus and brevis.

The anterior and posterior talofibular and the calcaneofibular ligaments were formerly described as the three fasciculi of the *external lateral ligament* of the ankle-joint.

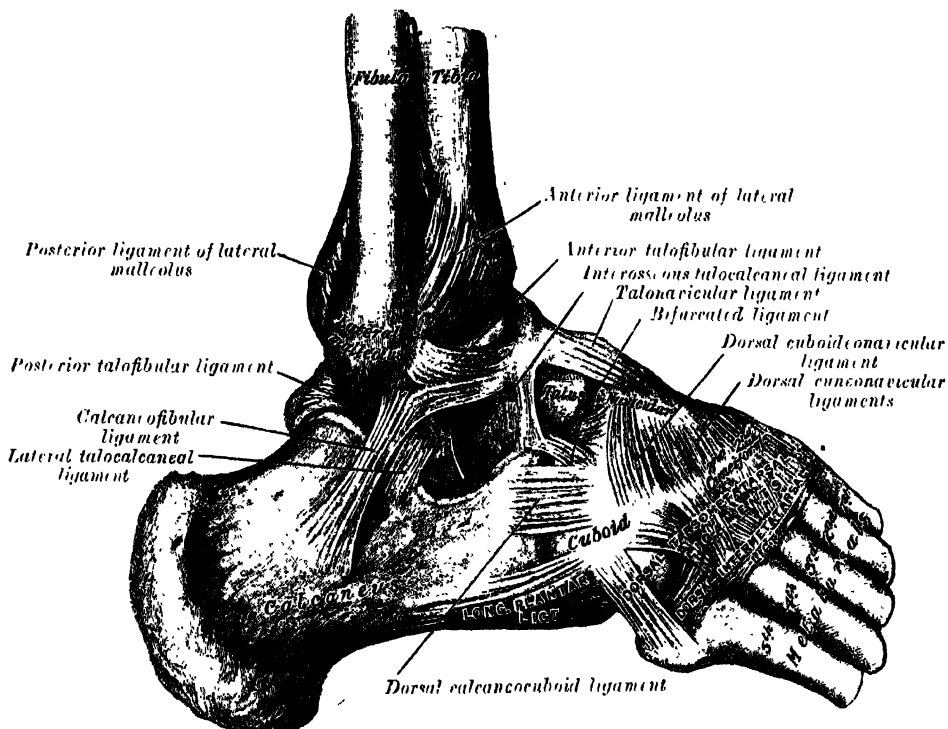
Relations.—The tendons, vessels, and nerves in relation with the joint are, in front, from the medial side, the Tibialis anterior, Extensor hallucis longus, anterior tibial vessels, deep peronæal nerve, Extensor digitorum longus, and Peronæus tertius; behind, from the medial side, the Tibialis posterior, Flexor digitorum longus, posterior tibial vessels, tibial nerve, Flexor hallucis longus; and, in the groove behind the fibular malleolus, the tendons of the Peronæi longus and brevis.

The *arteries* supplying the joint are derived from the malleolar branches of the anterior tibial and from the peronæal.

The *nerves* are derived from the deep peronæal and tibial.

Movements.—When the body is in the erect position, the foot is at right angles to the leg. The movements of the joint are those of dorsiflexion and extension; dorsiflexion consists in the approximation of the dorsum of the foot to the front of the leg, while in extension the heel is drawn up and the toes pointed downwards. The malleoli tightly embrace the talus in all positions of the joint, so that any slight degree of side-to-side movement which may exist is simply due to stretching of the ligaments of the talofibular syndesmosis, and slight bending of the body of the fibula. The superior articular surface of the talus is broader in front than behind. In dorsiflexion, therefore, greater space is required between the two malleoli. This is obtained by a slight outward rotatory movement of the lower end of the fibula and a stretching of the ligaments of the syndesmosis; this lateral

FIG. 510.—Ligaments of ankle and tarsus. Lateral aspect.



movement is facilitated by a slight gliding at the tibiofibular articulation, and possibly also by the bending of the body of the fibula. Of the ligaments, the deltoid is of great power—so much so, that it usually resists a force which fractures the process of bone to which it is attached. Its middle portion, together with the calcaneofibular ligament, binds the bones of the leg firmly to the foot, and resists displacement in every direction. Its anterior and posterior fibres limit extension and flexion of the foot respectively, and the anterior fibres also limit abduction. The posterior talofibular ligament assists the calcaneofibular in resisting the displacement of the foot backwards, and deepens the cavity for the reception of the talus. The anterior talofibular ligament is a security against the displacement of the foot forwards, and limits extension of the joint.

Extension of the foot upon the tibia and fibula is produced by the Gastrocnemius, Soleus, Plantaris, Tibialis posterior, Peronæi longus and brevis, Flexor digitorum longus, and Flexor hallucis longus; *dorsiflexion*, by the Tibialis anterior, Peronæus tertius, Extensor digitorum longus, and Extensor hallucis longus.*

Applied Anatomy.—As the ankle-joint is a very strong and powerful articulation, displacement of the talus from the tibiofibular mortise is a rare accident, and great force

* The student must bear in mind that the Extensor digitorum longus and Extensor hallucis longus are *extensors* of the toes, but *flexors* of the ankle; and that the Flexor digitorum longus and Flexor hallucis longus are *flexors* of the toes, but *extensors* of the ankle.

is required to produce it. Nevertheless, dislocation does occasionally occur, either anteroposteriorly or to one or other side. In the latter, which is the more common, fracture is a necessary accompaniment of the injury. The dislocation in these cases is somewhat peculiar, and is not a displacement in a horizontal direction, such as usually occurs in dislocations of ginglymoid joints, but the talus undergoes a partial rotation round an anteroposterior axis drawn through its own centre, so that the superior surface, instead of being directed upwards, is inclined more or less medialwards or lateralwards according to the variety of the displacement.

The ankle-joint is more frequently sprained than any joint in the body, and this may lead to acute synovitis. In these cases, when the synovial sac is distended with fluid, the bulging appears principally in the front of the joint, beneath the anterior tendons, and on either side, between the Tibialis anterior and the deltoid ligament on the medial side, and between the Peroneus tertius and the anterior talofibular ligament laterally. In addition to this, bulging often occurs posteriorly, and a fluctuating swelling may be detected on either side of the tendo calcaneus. A large proportion of so-called 'sprains' of the ankle have been proved by x-ray examination to be some variety of fracture about the malleoli, with or without displacement.

Chronic synovitis may result from frequent sprains, and when once this joint has been sprained it is liable to a recurrence of the injury; or the synovitis may be tuberculous in its origin, the disease usually beginning in the talus and extending to the joint, though it may commence in the synovial stratum of the articular capsule, the result probably of some slight strain in a tuberculous subject.

Excision of the ankle-joint is not often performed, since the foot after excision is often of very little use; far less useful, in fact, than after Syme's amputation, which is, therefore, a preferable operation in these cases. Further, disease of the ankle-joint is frequently associated with disease of the tarsal bones.

VII. INTERTARSAL ARTICULATIONS

1. TALOCALCANEAL ARTICULATION

The articulations between the calcaneus and talus are two in number— anterior and posterior. Of these, the anterior forms part of the talocalcaneonavicular joint, and will be described with that articulation. The posterior or talocalcaneal articulation is formed between the posterior calcaneal facet on the inferior surface of the talus, and the posterior facet on the superior surface of the calcaneus. It is an arthrodial joint, and the two bones are connected by an articular capsule and by anterior, posterior, lateral, medial, and interosseous talocalcaneal ligaments.

The **articular capsule** envelops the joint, and consists for the most part of short fibres; it is split up into distinct slips, and between these there is only a weak fibrous investment. It is lined by a synovial stratum, and the joint-cavity does not communicate with any of the other tarsal joints.

The **anterior talocalcaneal ligament** (fig. 513) extends from the front and lateral surface of the neck of the talus to the superior surface of the calcaneus.

The **posterior talocalcaneal ligament** (fig. 509) connects the lateral tubercle on the posterior surface of the talus with the upper and medial part of the calcaneus; it is a short band, and its fibres radiate from their narrow attachment to the talus.

The **lateral talocalcaneal ligament** (figs. 507, 510) is a short, strong fasciculus, passing from the lateral surface of the talus, immediately beneath its fibular facet, to the lateral surface of the calcaneus. It is placed in front of, but on a deeper plane than, the calcaneofibular ligament, with the fibres of which it is parallel.

The **medial talocalcaneal ligament** connects the medial tubercle on the posterior surface of the talus with the back of the sustentaculum tali. Its fibres blend with those of the plantar calcaneonavicular ligament.

The **interosseous talocalcaneal ligament** (figs. 507, 511) is very thick and strong, and forms the chief bond of union between the bones. It is, in fact, a portion of the united capsules of the talocalcaneonavicular and the talocalcaneal joints, and consists of two partially united layers of fibres, one belonging to the former and the other to the latter joint. It is attached, above, to the sulcus tali; below, to the sulcus calcanei.

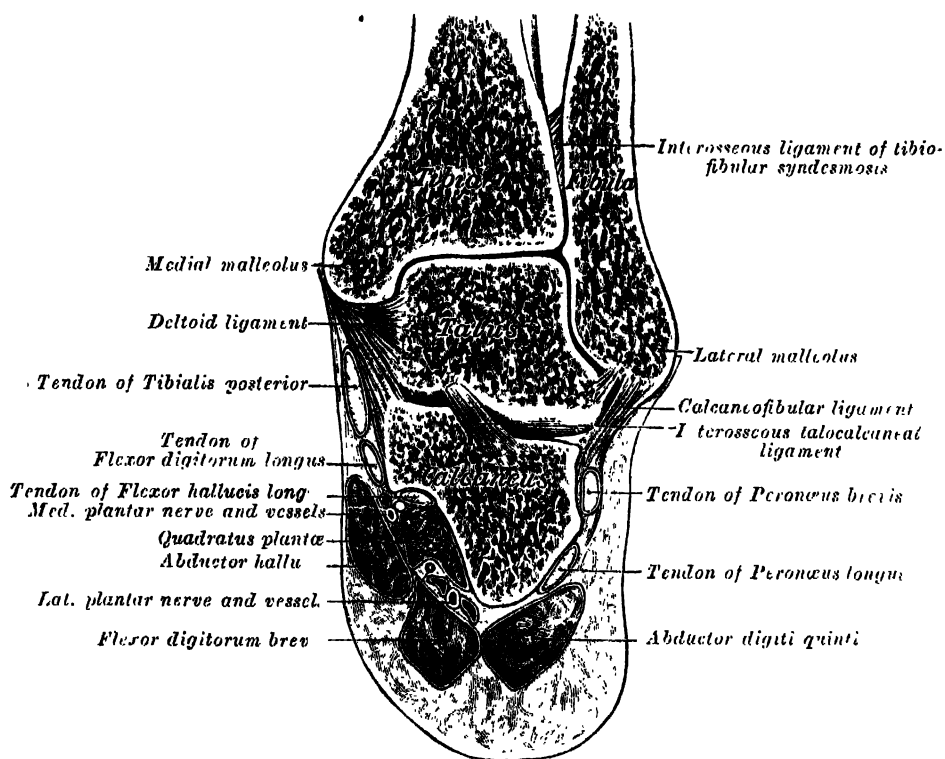
Movements.—The movements permitted between the talus and calcaneus are limited to gliding of the one bone on the other, backwards and forwards and from side to side.

2. TALOCALCANEONAVICULAR ARTICULATION

This articulation is an arthrodial joint: the rounded head of the talus being received into the concavity formed by the posterior surface of the navicular bone, the anterior articular surface of the calcaneus, and the upper surface of the plantar calcaneonavicular ligament. There are two ligaments in this joint; the articular capsule and the talonavicular.

The **articular capsule** is imperfectly developed except posteriorly, where it is considerably thickened and forms, with a part of the capsule of the talocalcaneal joint, the strong interosseous ligament which fills the sinus tarsi formed by the opposing sulci on the calcaneus and talus, as above mentioned.

FIG. 511.—Coronal section through right talocrural and talocalcaneal joints.



The **talonavicular ligament** (fig. 509) is a broad, thin band, connecting the neck of the talus to the dorsal surface of the navicular bone; it is covered by the Extensor tendons. The plantar calcaneonavicular supplies the place of a plantar ligament for this joint.

Movements.—This articulation permits of a considerable range of gliding movements.

3. CALCANEOCUBOID ARTICULATION

The ligaments connecting the calcaneus with the cuboid bone are five in number, viz. the articular capsule, the dorsal calcaneocuboid, the calcaneocuboid part of the bifurcated ligament, the long plantar, and the plantar calcaneocuboid.

The **articular capsule** contains certain bands, which form the other ligaments of the joint. Its synovial stratum is distinct from that of the other tarsal articulations (fig. 514):

The **dorsal calcaneocuboid ligament** (fig. 510) is a thin but broad fasciculus, which passes between the contiguous surfaces of the calcaneus and the cuboid bone, on the dorsal surface of the joint.

The **bifurcated ligament** (figs. 510, 513) is a strong band attached behind to the deep hollow on the upper surface of the calcaneus and dividing in front in a Y-shaped manner into a calcaneocuboid and a calcaneonavicular part. The *calcaneocuboid part* is fixed to the medial side of the cuboid bone and forms one of the principal bonds between the first and second rows of the tarsal bones. The *calcaneonavicular part* is attached to the lateral side of the navicular bone.

The **long plantar ligament** (fig. 512), the longest of the tarsal ligaments, is attached behind to the plantar surface of the calcaneus in front of the tuberosity, and in front to the tuberosity on the plantar surface of the cuboid bone, the more superficial fibres being continued forwards to the bases of the second, third, and fourth metatarsal bones. This ligament converts the groove on the plantar surface of the cuboid bone into a canal for the tendon of the Peronæus longus.

FIG. 512.—Ligaments of plantar surface of the right foot.



The **plantar calcaneocuboid ligament** (fig. 512) lies nearer to the bones than the preceding, from which it is separated by a little areolar tissue. It is a short but wide band of great strength, and extends from the tubercle and the depression in front of it, on the fore part of the plantar surface of the calcaneus, to the plantar surface of the cuboid bone behind the peroneal groove.

Movements. The movements permitted between the calcaneus and the cuboid bone are limited to slight gliding of the bones upon each other.

The *transverse tarsal joint* is formed by the articulation of the calcaneus with the cuboid bone, and the articulation of the talus with the navicular bone. The movement which takes place in this joint is more extensive than that in the other tarsal joints, and consists of a sort of rotation by means of which the foot may be slightly flexed or extended, the sole being at the same time carried medialwards (inverted) or lateralwards (everted).

4. LIGAMENTS CONNECTING THE CALCANEUS AND NAVICULAR

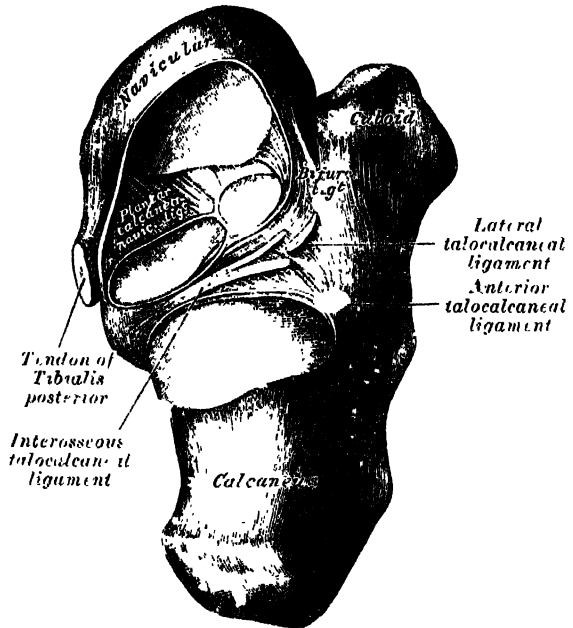
Though the calcaneus and the navicular bones do not directly articulate, they are connected by two ligaments: the calcaneonavicular part of the bifurcated, and the plantar calcaneonavicular.

The calcaneonavicular part of the bifurcated ligament is described above.

The **plantar calcaneonavicular ligament** (fig. 513) is a broad, thick band connecting the anterior margin of the sustentaculum tali of the calcaneus to the plantar surface of the navicular bone. This ligament not only unites the calcaneus with the navicular bone, but supports the head of the talus, forming part of the articular cavity in which it is received. The *dorsal surface* of the ligament presents a fibrocartilaginous facet, lined by the synovial stratum, and upon this a portion of the head of the talus rests. Its *plantar surface* is supported by the tendon of the Tibialis posterior; its *medial border* is blended with the anterior part of the deltoid ligament of the ankle-joint. The plantar calcaneonavicular and plantar calcaneocuboid ligaments together form the *deep ligament* of the tarsus.

Applied Anatomy.—The plantar calcaneonavicular ligament, by supporting the head of the talus, is concerned in maintaining the arch of the foot. When it yields the head of the talus is pressed downwards, medialwards, and forwards by the weight of the body, and the foot becomes flattened, expanded, and turned lateralwards, and exhibits the condition known as *flat-foot*. This ligament contains a considerable amount of elastic tissue, so as to give elasticity to the arch and spring to the foot; hence it is sometimes called the 'spring' ligament. It is supported, on its plantar surface, by the tendon of the Tibialis posterior, which spreads out at its insertion into a number of fasciculi, to be attached to most of the tarsal and metatarsal bones. This prevents undue stretching of the ligament, and is a protection against the occurrence of flat-foot; hence muscular weakness is, in most cases, the primary cause of the deformity.

FIG. 513. - Talocalcaneal and talocalcaneonavicular articulations exposed from above by removing the talus.



5. CUNEONAVICULAR ARTICULATION.

The navicular bone is connected to the three cuneiform bones by dorsal and plantar ligaments.

The **dorsal ligaments** are three small fasciculi, one attached to each of the cuneiform bones. The fasciculus connecting the navicular bone with the first cuneiform bone is continuous round the medial side of the articulation with the plantar ligament which unites these two bones.

The **plantar ligaments** have a similar arrangement to the dorsal, and are strengthened by slips from the tendon of the Tibialis posterior.

Movements.—Gliding movements are permitted between the navicular and cuneiform bones.

6. CUBOIDCUNEONAVICULAR ARTICULATION

The cuboid bone is connected with the navicular bone by dorsal, plantar, and interosseous ligaments.

The **dorsal ligament** extends obliquely forward and lateralwards, while the **plantar** passes nearly transversely from the cuboid bone to the navicular bone.

The **interosseous ligament** consists of strong transverse fibres, and connects the rough non-articular portions of the adjacent surfaces of the two bones.

Movements.—The movements permitted between the navicular and cuboid bones are limited to a slight gliding upon each other.

7. INTERCUNEIFORM AND CUNEOCUBOID ARTICULATIONS

The three cuneiform bones and the cuboid bone are connected together by dorsal, plantar, and interosseous ligaments.

The **dorsal and plantar ligaments** each consist of three transverse bands: one connects the first and second cuneiform bones, another the second and third cuneiform bones, and another the third cuneiform and cuboid bones. The **plantar ligaments** are strengthened by slips from the tendon of the Tibialis posterior.

The **interosseous ligaments** connect the rough non-articular portions of the adjacent surfaces of the bones.

Movements.—The movements permitted between these bones are limited to a slight gliding upon each other.

Applied Anatomy.—In spite of the great strength of the ligaments which connect the tarsal bones together, dislocation at some of the tarsal joints does occasionally occur. When this takes place, it is most commonly in connexion with the talus; for not only may this bone be dislocated from the tibia and fibula at the ankle-joint, but the other bones may be dislocated from it, the talus remaining *in situ* in the tibiofibular mortise. This constitutes what is known as the *subtalar* dislocation. Or, again, the talus may be dislocated from all its connexions—from the tibia and fibula above, the calcaneus below, and the navicular in front—and may even undergo a rotation, on either a vertical or a horizontal axis. In the former case the long axis of the bone is directed across the joint, so that the head faces the articular surface on one or other malleolus; in the latter, the collateral surfaces are directed upwards and downwards, so that the superior surface faces to one or the other side. Reduction in these cases is often very difficult or impossible, and the displaced talus may require removal by open operation. Dislocation may also occur at the transverse tarsal joint, the anterior tarsal bones being luxated from the talus and calcaneus. The other tarsal bones are occasionally, though rarely, dislocated from their connexions.

VIII. TARSOMETATARSAL ARTICULATIONS

These are arthrodial joints. The bones entering into their formation are the first, second, and third cuneiform, and the cuboid, and they articulate with the bases of the metatarsal bones. The first metatarsal bone articulates with the first cuneiform bone; the second is deeply wedged in between the first and third cuneiform bones, articulating by its base with the second cuneiform bone; the third articulates with the third cuneiform bone; the fourth, with the cuboid and third cuneiform bones; and the fifth with the cuboid bone. The bones are connected by dorsal, plantar, and interosseous ligaments.

The **dorsal ligaments** are strong, flat bands. The first metatarsal is joined to the first cuneiform bone by an articular capsule; the second has three bands, one from each cuneiform bone; the third has one from the third cuneiform bone; the fourth has one from the third cuneiform bone and one from the cuboid bone; and the fifth, one from the cuboid bone.

The **plantar ligaments** consist of longitudinal and oblique bands, disposed with less regularity than the dorsal ligaments. Those for the first and second metatarsal bones are the strongest; the second and third metatarsal bones are joined by oblique bands to the first cuneiform bone; the fourth and fifth metatarsal bones are connected by a few fibres to the cuboid bone.

The **interosseous ligaments** are three in number. The first is the strongest and passes from the lateral surface of the first cuneiform bone to the adjacent angle of the second metatarsal bone. The second connects the third cuneiform bone with the adjacent angle of the second metatarsal bone. The third connects the lateral angle of the third cuneiform bone with the adjacent side of the base of the third metatarsal bone.

Movements.—The movements permitted between the tarsal and metatarsal bones are limited to slight gliding of the bones upon each other.

Nerve Supply.—The intertarsal and tarsometatarsal joints are supplied by the deep peroneal nerve.

IX. INTERMETATARSAL ARTICULATIONS

The base of the first metatarsal bone is not connected with that of the second by any ligaments; in this respect the great toe resembles the thumb.

The bases of the second, third, fourth, and fifth metatarsal bones are connected by dorsal, plantar, and interosseous ligaments.

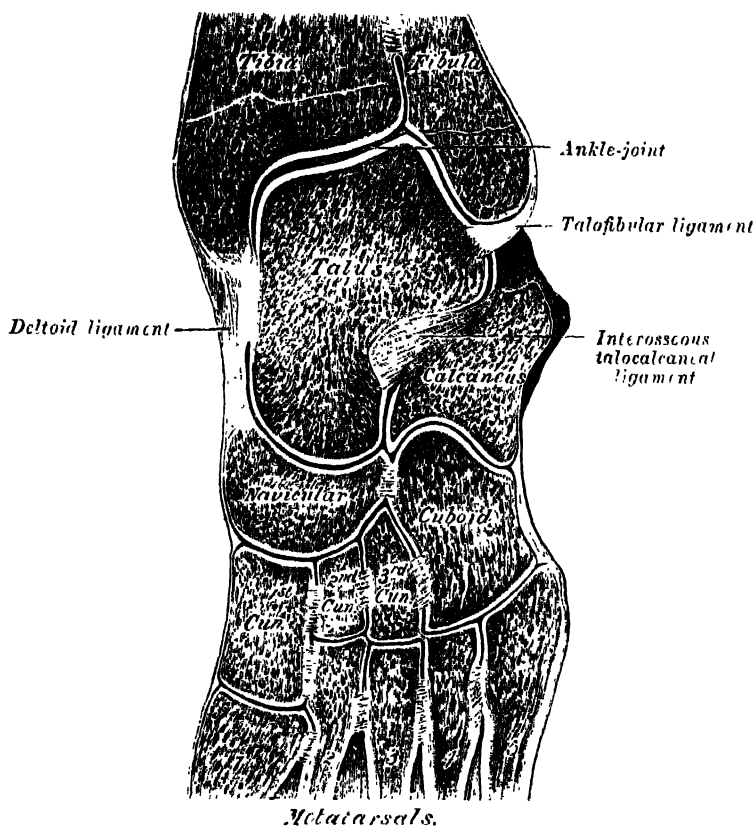
The heads of all the metatarsal bones are connected by the transverse metatarsal ligament.

The **dorsal and plantar ligaments** pass transversely between the bases of the adjacent bones.

The **interosseous ligaments** consist of strong transverse fibres which connect the rough non-articular portions of the adjacent surfaces.

The **transverse metatarsal ligament** is a narrow band which runs across and connects together the heads of all the metatarsal bones; it is blended anteriorly with the accessory plantar ligaments of the metatarsophalangeal articulations. Its plantar surface is concave where the flexor tendons run

FIG. 514.—Oblique section of left intertarsal and tarsometatarsal articulations, showing the synovial cavities.



below it; above it the tendons of the Interossei pass to their insertions. It differs from the transverse metacarpal ligament in that it connects the first metatarsal to the others.

Movements.—The movements permitted between the tarsal ends of the metatarsal bones are limited to a slight gliding of the articular surfaces one upon another.

The **synovial cavities** (fig. 514) present in the articulations of the tarsus and metatarsus are six in number: one for the talocalcaneal articulation; a second for the talocalcaneonavicular articulation; a third for the calcaneo-cuboid articulation; a fourth for the cuneonavicular, intercuneiform, and cuneocuboid articulations, the articulations of the second and third cuneiform bones with the bases of the second and third metatarsal bones, and the adjacent surfaces of the base of the second, third, and fourth metatarsal bones; a fifth for the first cuneiform bone with the metatarsal bone of the great toe; and a sixth, for the articulation of the cuboid bone with the fourth and fifth metatarsal bones. A small synovial cavity is sometimes found between the contiguous surfaces of the navicular and cuboid bones.

X. METATARSOPHALANGEAL ARTICULATIONS

The metatarsophalangeal articulations are of the condyloid kind, formed by the reception of the rounded heads of the metatarsal bones in shallow cavities on the bases of the first phalanges.

The ligaments are the accessory plantar and collateral.

The **accessory plantar ligaments** (glenoid ligaments of Cruveilhier) are thick, dense, fibrous structures. They are placed on the plantar surfaces of the joints in the intervals between the collateral ligaments, to which they are connected; they are loosely united to the metatarsal bones, but very firmly to the bases of the first phalanges. Their plantar surfaces are intimately blended with the transverse metatarsal ligament, and grooved for the flexor tendons, the sheaths surrounding which are connected to the sides of the grooves; their deep surfaces form parts of the articular facets for the heads of the metatarsal bones.

The **collateral ligaments** are two strong, rounded cords, placed on the sides of the joints; each is attached by one end to the posterior tubercle on the side of the head of the metatarsal bone, and by the other to the contiguous extremity of the phalanx.

The place of *dorsal ligaments* is supplied by the extensor tendons on the dorsal surfaces of the joints.

Movements.—The movements permitted in the metatarsophalangeal articulations are flexion, extension, adduction, and abduction.

XI. ARTICULATIONS OF THE DIGITS

The interphalangeal articulations are ginglymoid joints and each has a plantar and two collateral ligaments.

The arrangement of the ligaments is similar to that in the metatarsophalangeal articulations: the extensor tendons supply the places of dorsal ligaments.

Movements.—The only movements permitted in the joints of the digits are flexion and extension; these movements are more extensive between the first and second phalanges than between the second and third. The amount of flexion is very considerable, but extension is limited by the plantar and collateral ligaments.

Applied Anatomy.—Gout peculiarly affects the metatarsophalangeal joint of the big toe, beginning with the deposit of sodium and calcium urates in the articular cartilages. Later the circumarticular fibrous tissue becomes the seat of these gouty deposits, and considerable thickening and deformity may result.

Chronic arthritis with much enlargement of the head of the first metatarsal bone is often seen, giving rise to stiffness and pain on walking. The condition is termed *hallux rigidus*, and if, as frequently happens, it is accompanied by a displacement of the proximal phalanx lateralwards on the head of the metatarsal bone, *hallux valgus* is the resulting condition. The latter is commonly associated with the development of a bunion on the medial aspect of the thickened metatarsal head, while the second toe becomes contracted and deformed and assumes the condition known as *hammer toe*. This is especially the case if the individual has been in the habit of wearing tightly fitting boots, more particularly if the medial margin of the sole slopes lateralwards. The hammer toe deformity consists of an extreme flexion of the proximal interphalangeal joint with a hyperextension of the distal joint, and the big toe lies either on the dorsal or plantar aspect of the second toe.

Septic arthritis of the first metatarsophalangeal joint is seen in association with perforating ulcer of the foot, not uncommon in diabetes or locomotor ataxia.



ARCHES OF THE FOOT

In order that it may support the weight of the body in the erect posture with the least expenditure of material, the foot is constructed of a series of arches formed by the tarsal and metatarsal bones, and strengthened by the ligaments and tendons of the foot.

The main arches are the anteroposterior arches, which may be regarded as divisible into two types—a medial and a lateral.

The *medial arch* (fig. 515) is made up by the calcaneus, the talus, the navicular, the three cuneiform, and the first, second, and third metatarsal bones. Its summit is at the superior articular surface of the talus, and its two extremities or piers,

on which it rests in standing, are the tuberosity on the plantar surface of the calcaneus posteriorly, and the heads of the first, second, and third metatarsal bones anteriorly. The chief characteristic of this arch is its elasticity, due to its height and to the number of joints between its component parts. Its weakest part, i.e. the part most liable to yield from over-pressure, is the joint between the talus and the navicular bone, but this is braced by the plantar calcaneonavicular ligament, which is elastic and is thus able quickly to restore the arch to its pristine condition when the disturbing force is removed. This ligament is strengthened medially by blending with the deltoid ligament of the ankle-joint, and is supported inferiorly by the tendon of the *Tibialis posterior*. The arch is further supported by the

FIG. 515.—Skeleton of foot. Medial aspect.

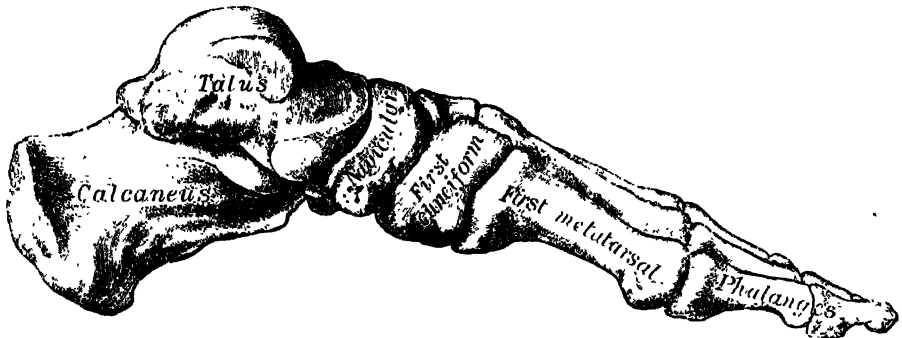
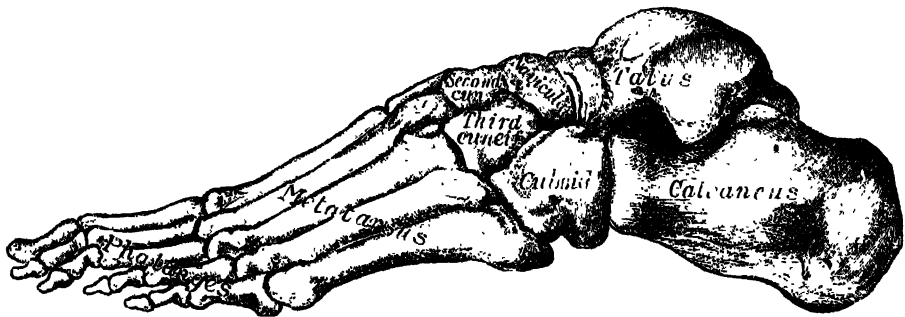


FIG. 516.—Skeleton of foot. Lateral aspect.



plantar aponeurosis, by the small muscles in the sole of the foot, by the tendons of the *Tibialis anterior* and *Peronæus longus*, and by the ligaments of all the articulations involved.

The *lateral arch* (fig. 516) is composed of the calcaneus, the cuboid, and the fourth and fifth metatarsal bones. Its summit is at the talocalcaneal articulation, and its chief joint is the calcaneocuboid, which possesses a special mechanism for locking, and allows only a limited movement. The most marked features of this arch are its solidity and its slight elevation; two strong ligaments, the long plantar and the plantar calcaneocuboid, together with the extensor tendons and the short muscles of the little toe, preserve its integrity.

While the medial and lateral arches may be readily demonstrated, as the component anteroposterior arches of the foot, yet the *fundamental longitudinal arch* is contributed to by both, and consists of the calcaneus, cuboid, third cuneiform, and third metatarsal bones: all the other bones of the foot may be removed without destroying this arch.

In addition to the longitudinal arches the foot presents a series of transverse arches. At the posterior part of the metatarsus and the anterior part of the tarsus the arches are complete, but in the middle of the tarsus they present more the characters of half-domes the concavities of which are directed downwards and medialwards, so that when the medial borders of the feet are placed in apposition a

complete tarsal dome is formed. The transverse arches are strengthened by the interosseous, plantar, and dorsal ligaments, by the short muscles of the first and fifth toes (especially the transverse head of the Adductor hallucis), and by the Peronæus longus, whose tendon stretches between the piers of the arches.

Applied Anatomy.—*Pes planus* or flat-foot is a very common deformity due to the disappearance of the arches of the foot from subsidence dependent on stretching of the plantar ligaments. In its early stages before the deformity is marked it is accompanied by considerable pain from pressure on the plantar nerves, but when the condition is fully formed and the head of the talus has descended completely, the condition is painless but irremediable.

The stretching of the ligaments in this condition is most often due to muscular weakness in young adults who may have to stand for long periods daily. The deep muscles, especially the posterior tibial group, by their tonicity are the most potent in maintaining the longitudinal arch, and when overtired they relax and throw the strain on the plantar ligaments which yield secondarily. All three posterior tibial muscles are effective in thus supporting the longitudinal arch, but perhaps the most important one is the Flexor hallucis longus which normally stretches like a bow-string across the whole antero-posterior length of the arch.

The transverse arch subsequently disappears, this having been largely held up by the Peronæus longus. In the treatment of this static form of flat-foot, muscular rest is essential in the early stages, as once the ligamentous tissues are stretched, they are unable to return to their original condition.

There are, however, other forms of flat-foot, viz. the congenital, and the paralytic (due to affections of the centres supplying the post-tibial group of muscles); those due to inflammation of the tarsal joints and those following injuries to the tarsus and metatarsus. If in the two latter forms the patient put his weight on the foot before the normal condition has been fully established, *pes planus* is certain to result, and the arches will not be capable of restoration subsequently.

Pes cavus, the opposite of *pes planus*, is usually due to some contracture of the posterior tibial group in certain affections of the medulla spinalis. It is also commonly seen in association with talipes equinus or equinovarus, and here the longitudinal arching of the foot is greatly increased, with contraction of the plantar aponeurosis which in some instances becomes very pronounced.

MYOLOGY*

THE Muscles are connected with the bones, cartilages, ligaments, and skin, either directly, or through the intervention of fibrous structures called tendons or aponeuroses. Where a muscle is attached to bone or cartilage, the fibres end in blunt extremities upon the periosteum or perichondrium, and do not come into direct relation with the osseous or cartilaginous tissue. Where muscles are connected with the skin, they lie as a flattened layer beneath it, and are united with its areolar tissue by larger or smaller bundles of fibres.

Muscles vary in their form. In the limbs, they are of considerable length, especially the more superficial ones; they surround the bones, and constitute an important protection to the joints. In the trunk, they are broad and flattened, and assist in forming the walls of the trunk cavities. Hence the reason of the terms, *long*, *broad*, *short*, &c., used in the description of muscles.

There is considerable variation in the arrangement of the fibres of certain muscles with reference to the tendons to which they are attached. In some muscles the fibres are parallel and run directly from their origin to their insertion; these are quadrilateral muscles, such as the Thyreo-hyoideus. A modification of these is found in the fusiform muscles, in which the fibres are not quite parallel, but slightly curved, so that the muscle tapers at either end; in their mode of action, however, they resemble the quadrilateral muscles. In other muscles the fibres arise by a broad origin and converge to a narrow or pointed insertion; this arrangement is found in the triangular muscles—e.g. the Temporalis. In some muscles, which otherwise would belong to the quadrilateral or triangular type, the origin and insertion are not in the same plane, the plane of the line of origin intersecting that of the line of insertion: such is the case in the Pectineus. In some muscles (e.g. the Peronæi) the fibres are oblique and are attached to one side of a tendon; such muscles are termed unipennate. A modification of this condition is found where oblique fibres are fixed to both sides of a central tendon; such muscles are called bipennate, and an example is afforded in the Rectus femoris. Finally, there are muscles in which the fibres are arranged in curved bundles in one or more planes, as in the Sphincters. The arrangement of the fibres is of considerable importance in respect to the relative strength and range of movement of the muscle. Those muscles where the fibres are long and few in number have great range, but diminished strength; where, on the other hand, the fibres are short and more numerous, there is great power, but lessened range.

The names applied to the various muscles have been derived: 1, from their situation, as the Tibialis anterior, Tibialis posterior; 2, from their direction, as the Rectus abdominis, Obliqui capitis, Transversus abdominis; 3, from their uses, as Flexors, Extensors, Abductors, &c.; 4, from their shape, as the Deltoides, Rhomboideus; 5, from the number of their divisions, as the Biceps, and Triceps; 6, from their attachment, as the Sternocleidomastoideus, Sternohyoideus, Sternothyroideus.

* The muscles and fasciæ are described conjointly, in order that the student may consider the arrangement of the latter in his dissection of the former. It is rare for the student of anatomy in this country to have the opportunity of dissecting the fasciæ separately; and it is for this reason, as well as from the close connexion that exists between the muscles and their investing sheaths, that they are considered together. Some general observations are first made on the anatomy of the muscles and fasciæ, the special descriptions being given in connexion with the different regions.

In the description of a muscle, the term *origin* is meant to imply its more fixed or central attachment; and the term *insertion* the movable point on which the force of the muscle is applied; but the origin is absolutely fixed in only a small number of muscles, such as those of the face which are attached by one extremity to immovable bones, and by the other to the movable integument; in the greater number, the muscle can be made to act from either extremity.

In the dissection of the muscles, attention should be directed to the exact *origin*, *insertion*, and *actions* of each, and to its more important *relations* with surrounding parts. While accurate knowledge of the points of attachment of the muscles is of great importance in determining their actions, it is not to be regarded as conclusive. The action of the muscle deduced from its attachments, or even by pulling on it in the dead subject, is not necessarily its action in the living. By pulling, for example, on the Brachioradialis in the cadaver the hand may be slightly supinated when in the prone position and slightly pronated when in the supine position, but there is no evidence that these actions are performed by the muscle during life. It is impossible for an individual to throw into action any one muscle; in other words, movements, not muscles, are represented in the central nervous system. To carry out a movement a definite combination of muscles is called into play, and the individual has no power either to leave out a muscle from this combination, or to add one to it. One (or more) muscle of the combination is the chief moving force; when this muscle passes over more than one joint, other muscles (synergic muscles) come into play to inhibit the movements not required; a third set of muscles (fixation muscles) fix the limb—i.e. in the case of the limb-movements—and also prevent disturbances of the equilibrium of the body generally. As an example, the movement of the closing of the fist may be considered: (1) the prime movers are the Flexores digitorum, Flexor pollicis longus, and the small muscles of the thumb; (2) the synergic muscles are the Extensores carpi, which prevent flexion of the wrist; while (3) the fixation muscles are the Biceps and Triceps brachii, which steady the elbow and shoulder. A further point which must be borne in mind in considering the actions of muscles is that in certain positions a movement can be effected by gravity, and in such a case the muscles acting are the antagonists of those which might be supposed to be in action. Thus in flexing the trunk when no resistance is interposed the Sacrospinales contract to regulate the action of gravity, and the Recti abdominis are relaxed.*

The minute anatomy of muscular tissue is described on pp. 30 to 34.

Applied Anatomy.—By a consideration of the actions of the muscles, the surgeon is able to explain the causes of displacement in various forms of fracture, and the causes which produce distortion in various deformities, and, consequently, to adopt appropriate treatment in each case. The relations, also, of some of the muscles, especially those in immediate apposition with the larger blood-vessels, and the surface markings they produce, should be remembered, as they form useful guides in the application of ligatures to those vessels. Degeneration of muscular tissue is important clinically, and is met with in two main conditions. In one, the degeneration is myopathic, or primary in the muscles themselves; in the other it is neuropathic, or secondary to some lesion of the nervous system—a hemorrhage into the brain, for example, or injury or inflammation of some part of the medulla spinalis or peripheral nerves. In either case more or less paralysis and atrophy of the affected muscles result. When the degeneration begins primarily in the muscles, however, it often happens that though the muscle-fibres waste away, their place is taken by fibrous and fatty tissue to such an extent that the affected muscles increase in volume, and actually appear to hypertrophy.

Ossification of muscular tissue as a result of repeated strain or injury is not infrequent. It is oftenest found about the tendon of the Adductor longus and Vastus medialis in horsemen, or in the Pectoralis major and Deltoideus of soldiers. It may take the form of exostoses firmly fixed to the bone—e.g. 'rider's bone' on the femur—or of layers or spicules of bone lying in the muscles or their fasciæ and tendons. Busse states that these bony deposits are preceded by a hemorrhagic myositis due to injury, the effused blood organising and being finally converted into bone. In the rarer disease, progressive myositis ossificans, there is an unexplained tendency for practically any of the voluntary muscles to become converted into solid and brittle bony masses which are completely rigid.

* Consult in this connexion the Croonian Lectures (1903) on 'Muscular Movements and their representation in the Central Nervous System,' by Charles E. Beever, M.D.

TENDONS, APONEUROSES, AND FASCIÆ

Tendons are white, glistening cords, varying in length and thickness, and devoid of elasticity. They consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other and are firmly united together. They are very sparingly supplied with blood-vessels, the smaller tendons presenting in their interior no trace of them. Nerves supplying tendons end in what are known as neurotendinous spindles or organs of Golgi; these are described with the organs of the senses.

Aponeuroses are flattened or ribbon-shaped tendons, of a pearly-white colour, iridescent and glistening; they are only sparingly supplied with blood-vessels.

The tendons and aponeuroses connect the muscles with the movable structures, such as the bones and cartilages. Where the end of a muscle is continued directly into a tendon, the line of junction between the two is usually well-defined, but where the muscle meets the tendon obliquely, bundles of tendon fibres generally run for a variable distance into the substance of the muscle, so that the line of junction is irregular. Microscopic examination shows that, in either case, the tendon is subdivided into small bundles, corresponding in size and number with the fibres of the muscle. Each muscular fibre ends in a more or less rounded extremity covered by sarcolemma, and the fibres of each tendon bundle are intimately united with the sarcolemma covering the end of the muscular fibre. The mode of union is well shown when the muscle fibre has shrunk inside its sarcolemma.

The **fasciæ** are fibro-areolar or aponeurotic laminæ, of variable thickness and strength, found in all regions of the body, investing the softer and more delicate organs. During the process of development many of the cells of the mesoderm are differentiated into bones, muscles, vessels, &c.; the cells of the mesoderm which are not so utilised form an investment for these structures and are differentiated into the true skin and the fasciæ of the body. The fasciæ are subdivided into superficial and deep.

The *superficial fascia* is found immediately beneath the integument over almost the entire surface of the body. It connects the skin to the subjacent parts, and consists of fibro-areolar tissue, containing in its meshes pellicles of fat in varying quantity. It varies in thickness in different parts of the body; in the groin it is so thick that it may be subdivided into several laminæ. Beneath the fatty layer there is generally another layer of superficial fascia, almost devoid of adipose tissue, in which the trunks of the subcutaneous vessels and nerves and the superficial lymph-glands are found. Certain cutaneous muscles are situated in the superficial fascia, e.g. the *Platysma* and the muscles of the face. The superficial fascia is most distinct at the lower part of the abdomen, perinæum, and extremities; it is very thin in those regions where muscular fibres are inserted into the integument, as on the side of the neck, in the face, and around the anus. It is very dense in the scalp, palms of the hands, and soles of the feet, forming a fibrofatty layer, which binds the integument firmly to the underlying structures. It facilitates the movement of the skin, serves as a soft nidus for the passage of vessels and nerves to the skin, and retains the warmth of the body, since the fat contained in its areolæ is a bad conductor of heat.

The *deep fascia* is a dense, inelastic membrane, forming sheaths for the muscles, and in some cases affording them broad surfaces for attachment. It consists of shining tendinous fibres, placed parallel with one another, and connected together by other fibres disposed in a rectilinear manner. It forms a strong investment which not only binds down collectively the muscles in each region, but gives a separate sheath to each, as well as to the vessels and nerves. It assists the muscles in their actions by the degree of tension and pressure it makes upon their surfaces; in certain situations the degree of tension and pressure is regulated by muscles, as, for instance, by the *Tensor fasciæ latæ* and *Glutæus maximus* in the thigh, and the *Palmaris longus* in the hand. In the limbs, the fascia not only invests the limb, but gives off septa which separate the various muscles, and are attached to the periosteum: these prolongations of fasciæ are usually spoken of as intermuscular septa.

The fasciæ and muscles may be grouped into those of the head and neck; of the trunk; of the upper extremity; and of the lower extremity.

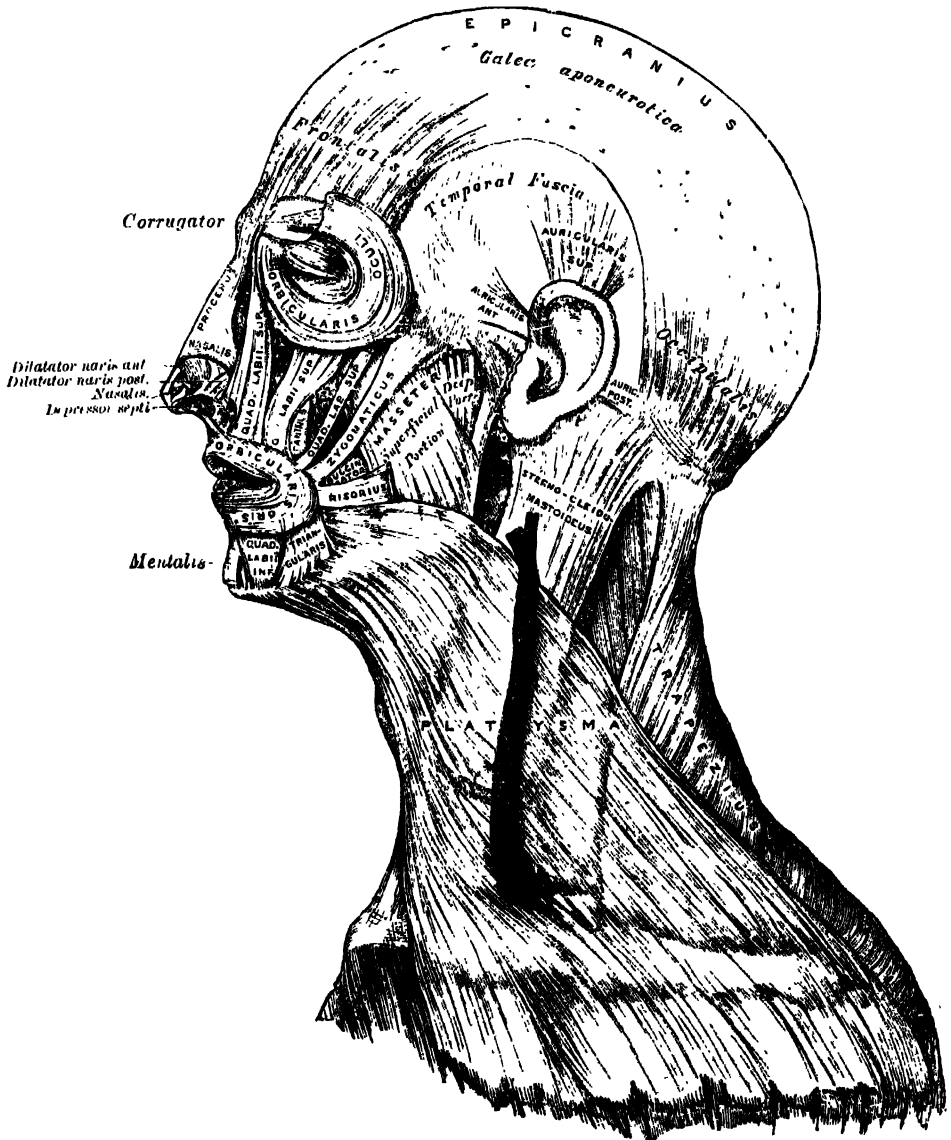
FASCIÆ AND MUSCLES OF THE HEAD

I. THE MUSCLE OF THE SCALP

Epicranius

The superficial fascia in the cranial region is a firm, fibrofatty layer, intimately adherent to the integument, and to the Epicranius and its tendinous aponeurosis; behind, it is continuous with the superficial fascia at the back of the neck: laterally, is prolonged over the temporal fascia.

FIG. 517.—Muscles of the head, face, and neck.



The **Epicranius** (*Occipitofrontalis*) (fig. 517) is a broad, musculo-fibrous layer, which covers the whole of one side of the vertex of the skull, from the occipital bone to the eyebrow. It consists of two parts, the *Occipitalis* and

the *Frontalis*, connected by an intervening tendinous aponeurosis, the *galea aponeurotica*.

The *Occipitalis*, thin and quadrilateral in form, arises by tendinous fibres from the lateral two-thirds of the superior nuchal line of the occipital bone, and from the mastoid part of the temporal. It ends in the *galea aponeurotica*.

The *Frontalis* is thin, of a quadrilateral form, and intimately adherent to the superficial fascia. It is broader than the *Occipitalis* and its fibres are longer and paler in colour. It has no bony attachments. Its medial fibres are continuous with those of the *Procerus*; its intermediate fibres blend with the *Corrugator* and *Orbicularis oculi*; and its lateral fibres are also blended with the latter muscle over the zygomatic process of the frontal bone. From these attachments the fibres are directed upwards, and join the *galea aponeurotica* below the coronal suture. The medial margins of the *Frontales* are joined together for some distance above the root of the nose; but between the *Occipitales* there is a considerable, though variable, interval, occupied by the *galea aponeurotica*.

The *galea aponeurotica* (epicranial aponeurosis) covers the upper part of the cranium; behind, it is attached, in the interval between the *Occipitales*, to the external occipital protuberance and highest nuchal lines of the occipital bone; in front, it forms a short and narrow prolongation between the *Frontales*. On either side it gives origin to the *Auriculares anterior* and *superior*; in this situation it loses its aponeurotic character, and is continued over the temporal fascia to the zygomatic arch. It is closely united to the integument by the firm, fibrofatty superficial fascia: it is connected to the pericranium by loose cellular tissue, which allows of the movement of the aponeurosis, the latter carrying with it the integument.

Nerves.—The *Occipitalis* is supplied by the posterior auricular branch of the facial nerve, and the *Frontalis* by the temporal branches of the same nerve.

Actions.—The *Occipitales* draw the scalp backwards; the *Frontales* raise the eyebrows and the skin over the root of the nose, and at the same time draw the scalp forwards, throwing the integument of the forehead into transverse wrinkles. By bringing alternately into action the *Occipitales* and *Frontales* the entire scalp may be moved backwards and forwards. In the ordinary action of the *Frontales*, the eyebrows are elevated, thus giving to the face the expression of surprise: if the action be exaggerated, the eyebrows are still further raised, and the skin of the forehead thrown into transverse wrinkles, as in the expression of fright or horror.

A thin muscular slip, the *Transversus nuchæ*, is present in about 25 per cent. of cases; it arises from the external occipital protuberance or from the superior nuchal line, either superficial or deep to the *Trapezius*; it is frequently inserted with the *Auricularis posterior*, but may join the posterior edge of the *Sternocleidomastoideus*.

Applied Anatomy.—From an anatomical point of view, the scalp consists of five layers, viz. the skin, subcutaneous tissue, *Epicranium* and its aponeurosis, subaponeurotic connective tissue, and pericranium. But from a surgical standpoint it is better to regard the first three of these structures as a single layer, since they are all intimately fused together, and when torn off in an accident, or turned down as a flap in a surgical operation, remain firmly connected to each other. In consequence of the dense character of the subcutaneous tissue, the amount of swelling which occurs as the result of inflammation is slight; and the edges of a wound which does not involve the *Epicranium* or its aponeurosis do not gape. The blood-vessels, also, which lie in this tissue, when wounded, do not contract and retract freely; and therefore the hæmorrhage from scalp wounds is often very considerable, but can always be arrested by pressure—a matter of great importance, as it is often very difficult or impossible to pick up with forceps a wounded vessel in the scalp.

The subaponeurotic connective tissue is, from a surgical point of view, of considerable importance. It is loose and lax, and is easily torn through; and hence, when the scalp is wounded, this is the tissue which is torn when the flap is separated from the parts beneath. The vessels are contained in the flap, and there is little risk of sloughing, unless the vitality of the part has been actually destroyed by the injury. In consequence of the loose nature of the subaponeurotic tissue, any septic inflammation is apt to assume a very diffuse form and spread over the skull, and, unless relieved by timely incisions, may lead to serious complications. Owing to the attachments of the aponeurosis to the zygomatic arch and highest nuchal line, subaponeurotic effusions sag down in these situations, but do not extend beyond to the infratemporal fossa, or into the neck; anteriorly, however, where there is no definite attachment to bone, the effusion will pass

the lacrimal ducts, but the majority are directly continuous with the palpebral part of the muscle and can be traced across the lids.

The *medial palpebral ligament* (*tendo oculi*), about 4 mm. in length and 2 mm. in breadth, is attached to the frontal process of the maxilla in front of the lacrimal groove. Crossing the lacrimal sac, it divides into two parts, upper and lower, each attached to the medial end of the corresponding tarsus. As the ligament crosses the lacrimal sac, an aponeurotic lamina is given off from its posterior surface; this expands over the sac, and is attached to the posterior lacrimal crest.

The *lateral palpebral raphe* is a much weaker structure than the medial palpebral ligament. It is attached to the margin of the frontosphenoidal process of the zygomatic bone, and passes medialwards to the lateral commissure of the eyelids, where it divides into two slips, which are fixed to the margins of the respective tarsi.

The **Corrugator** is a small pyramidal muscle, placed at the medial end of the eyebrow, beneath the Frontalis and Orbicularis oculi. It arises from the medial end of the superciliary arch; and its fibres pass upwards and lateralwards, between the palpebral and orbital portions of the Orbicularis oculi, and are inserted into the deep surface of the skin, above the middle of the orbital arch.

Nerves.—The Orbicularis oculi and Corrugator are supplied by the facial nerve.

Actions.—The Orbicularis oculi is the sphincter muscle of the eyelids. The palpebral portion acts involuntarily, closing the lids gently, as in sleep or in blinking; the orbital portion is subject to the will. When the entire muscle is brought into action, the skin of the forehead, temple, and cheek is drawn towards the medial angle of the orbit, and the eyelids are firmly closed. The skin thus drawn upon is thrown into folds, especially radiating from the lateral angle of the eyelids; these folds become permanent in old age, and form the so-called 'crow's feet.' The Levator palpebræ superioris is the direct antagonist of this muscle since it raises the upper eyelid and exposes the front of the bulb of the eye. The lacrimal part of the Orbicularis oculi draws the eyelids and the ends of the lacrimal canals medialwards, and applies them to the surface of the bulb of the eye, thus placing them in the most favourable situation for receiving the tears; it also compresses the lacrimal sac. The Corrugator draws the eyebrow downwards and medialwards, producing the vertical wrinkles of the forehead. It is the 'frowning' muscle, and may be regarded as the principal muscle in the expression of suffering.

III. MUSCLES OF THE NOSE (fig. 517)

Procerus.
Nasalis.

Depressor septi.
Dilatator naris posterior.

Dilatator naris anterior.

The **Procerus** (*Pyramidalis nasi*) is a small pyramidal slip arising by tendinous fibres from the fascia covering the lower part of the nasal bone and upper part of the lateral nasal cartilage; it is inserted into the skin over the lower part of the forehead between the two eyebrows, its fibres decussating with those of the Frontalis.

The **Nasalis** (*Compressor naris*) consists of two parts, transverse and alar. The *transverse part* arises from the maxilla, above and laterally to the incisive fossa; its fibres proceed upwards and medialwards, expanding into a thin aponeurosis which is continuous on the bridge of the nose with that of the muscle of the opposite side, and with the aponeurosis of the Procerus. The *alar part* is attached by one end to the greater alar cartilage, and by the other to the integument at the apex of the nose.

The **Depressor septi** arises from the incisive fossa of the maxilla; its fibres ascend to be inserted into the septum and back part of the ala of the nose. It lies between the mucous membrane and muscular structure of the lip.

The **Dilatator naris posterior** is placed partly beneath the Quadratus labii superioris. It arises from the margin of the nasal notch of the maxilla,

and from the lesser alar cartilages, and is inserted into the skin near the margin of the nostril.

The **Dilatator naris anterior** is a delicate fasciculus, passing from the greater alar cartilage to the integument near the margin of the nostril; it is situated in front of the preceding.

Nerves.—All the muscles of this group are supplied by the facial nerve.

Actions.—The **Procerus** draws down the medial angles of the eyebrows and produces transverse wrinkles over the bridge of the nose. The **Dilatatores** enlarge the apertures of the nares. Their action in ordinary breathing is to resist the tendency of the nares to close from atmospheric pressure, but in difficult breathing, as well as in some emotions, such as anger, they contract strongly. The **Depressor septi** is a direct antagonist of the other muscles of the nose, drawing the ala of the nose downwards, and thereby constricting the apertures of the nares. The **Nasalis** depresses the cartilaginous part of the nose and draws the ala towards the septum.

IV. MUSCLES OF THE MOUTH

Quadratus labii superioris.

Caninus.

Zygomaticus

Mentalis.

Quadratus labii inferioris.

Triangularis.

Buccinator.

Orbicularis oris.

Risorius.

The **Quadratus labii superioris** is a broad sheet, the origin of which extends from the side of the nose to the zygomatic bone. Its medial fibres form the *angular head*, which arises by a pointed extremity from the upper part of the frontal process of the maxilla, and passing obliquely downwards and lateralwards divides into two slips. One of these is inserted into the greater alar cartilage and skin of the nose; the other is prolonged into the lateral part of the upper lip, blending with the infraorbital head and with the **Orbicularis oris**. The intermediate portion or *infraorbital head* arises from the lower margin of the orbit immediately above the infraorbital foramen, some of its fibres being attached to the maxilla, others to the zygomatic bone. Its fibres converge, to be inserted into the muscular substance of the upper lip between the angular head and the **Caninus**. The lateral fibres form the *zygomatic head*, and are separated from the rest of the muscle by a narrow interval; they arise from the malar surface of the zygomatic bone immediately behind the zygomaticomaxillary suture and pass downwards and medialwards to the upper lip.

The **Caninus** (**Levator anguli oris**) arises from the canine fossa, immediately below the infraorbital foramen; its fibres are inserted into the angle of the mouth, intermingling with those of the **Zygomaticus**, **Triangularis**, and **Orbicularis oris**.

The **Zygomaticus** arises from the zygomatic bone, in front of the zygomaticotemporal suture, and descending obliquely with a medial inclination, is inserted into the angle of the mouth, where it blends with the fibres of the **Caninus**, **Orbicularis oris**, and **Triangularis**.

The **Mentalis** (**Levator menti**) is a conical fasciculus, situated at the side of the frenulum of the lower lip. It arises from the incisive fossa of the mandible, and descends to be inserted into the integument of the chin.

The **Quadratus labii inferioris** is a quadrilateral muscle. It arises from the oblique line of the mandible, between the symphysis and the mental foramen, and passes upwards and medialwards, to be inserted into the integument of the lower lip, its fibres blending with the **Orbicularis oris**, and with those of its fellow of the opposite side. At its origin it is continuous with the fibres of the **Platysma**. Much yellow fat is intermingled with the fibres of this muscle.

The **Triangularis** (**Depressor anguli oris**) arises from the oblique line of the mandible below and lateral to the **Quadratus labii inferioris**; its fibres converge and are inserted by a narrow fasciculus into the angle of the mouth. At its origin it is continuous with the **Platysma**, and at its insertion with the **Orbicularis oris** and **Risorius**; some of its fibres are directly continuous with

those of the Caninus, and others are occasionally found crossing from the muscle of one side to that of the other; these latter fibres constitute the *Transversus menti*.

The **Buccinator** (fig. 519) is a thin quadrilateral muscle, occupying the interval between the maxilla and the mandible at the side of the face. It arises from the outer surfaces of the alveolar processes of the maxilla and mandible, corresponding to the three molar teeth; and behind, from the anterior border of the pterygomandibular raphe which separates it from the Constrictor pharyngis superior. The fibres converge towards the angle of the mouth, where the central fibres intersect each other, those from below being continuous with the upper segment of the Orbicularis oris, and those from above with the lower segment; the highest and lowest fibres are continued forward into the corresponding lip without decussation.

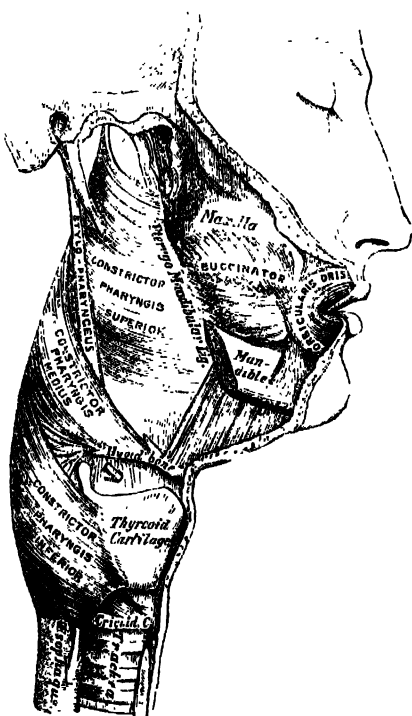
Relations.—The Buccinator is covered by the buccopharyngeal fascia, and is in relation by its *superficial surface*, behind, with a large mass of fat, which separates it from the ramus of the mandible, the Masseter, and a small portion of the Temporalis; this fat has been named the *suctorial pad*, because it is supposed to assist in the act of sucking. In front the superficial surface of the Buccinator is in relation with the Zygomaticus, Risorius, Caninus, Triangularis, and the parotid duct which pierces it opposite the second molar tooth of the maxilla; the external maxillary artery and anterior facial vein cross it from below upwards; it is also crossed by branches of the facial and buccinator nerves. The *deep surface* is in relation with the buccal glands and mucous membrane of the mouth.

The *pterygomandibular raphe* is a tendinous band of the buccopharyngeal fascia, attached by one extremity to the hamulus of the medial pterygoid lamina, and by the other to the posterior end of the mylohyoid line of the mandible. Its *medial surface* is covered by the mucous membrane of the mouth. Its *lateral surface* is separated from the ramus of the mandible by a quantity of adipose tissue. Its *posterior border* gives attachment to the Constrictor pharyngis superior; its *anterior border* to part of the Buccinator (fig. 519).

The **Orbicularis oris** (figs. 517, 520) is not a simple sphincter muscle like the Orbicularis oculi; it consists of numerous strata of muscular fibres surrounding the orifice of the mouth but having different directions. It consists partly of fibres derived from the other facial muscles which are inserted into the lips, and partly of fibres proper to the lips. Of the former, a considerable number are derived from the Buccinator, and form the deeper stratum of the Orbicularis. Some of the Buccinator fibres—namely, those near the middle of the muscle—decussate at the angle of the mouth, those arising from the maxilla passing to the lower lip, and those from the mandible to the upper lip. The uppermost and lowermost fibres of the Buccinator pass across the lips from side to side without decussation. Superficial to this is a second stratum, formed

on either side by the Caninus and Triangularis, which cross each other at the angle of the mouth; the fibres from the Caninus pass to the lower lip, and those from the Triangularis to the upper lip, along which they run, to be inserted into the skin near the median line. In addition to these there are fibres from the Quadratus labii superioris, the Zygomaticus, and the Quadratus labii

FIG. 519.—Muscles of the pharynx and cheek.



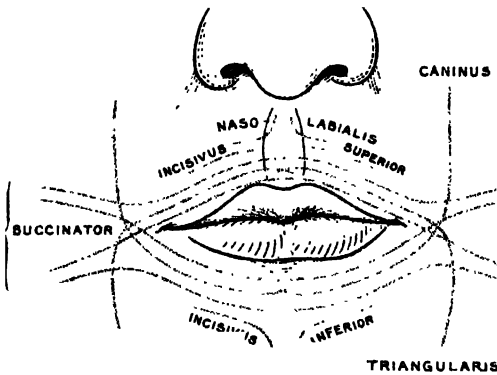
inferioris; these intermingle with the transverse fibres described above, and have principally an oblique direction. The proper fibres of the lips are oblique, and pass from the deep surface of the skin to the mucous membrane, through the thickness of the lip. Finally there are fibres by which the muscle is connected with the maxillæ and the septum of the nose above and with the mandible below. In the upper lip these consist of two bands, lateral and medial, on either side of the middle line; the lateral band (*m. incisivus labii superioris*) arises from the alveolar border of the maxilla, opposite the lateral incisor tooth, and arching lateralwards is continuous with the other muscles at the angle of the mouth; the medial band (*m. nasolabialis*) connects the upper lip to the back of the septum of the nose. The interval between the two medial bands corresponds with the depression, called the *philtrum*, seen on the lip beneath the septum of the nose. The additional fibres for the lower lip constitute a slip (*m. incisivus labii inferioris*) on either side of the middle line; this arises from the mandible, laterally to the Mentalis, and intermingles with the other muscles at the angle of the mouth.

The **Risorius** arises from the parotideomasseteric fascia and is inserted into the skin at the angle of the mouth (fig. 517). It is a narrow bundle of fibres, broadest at its origin, but varies much in its size and form.

Nerves.—The muscles in this group are all supplied by the facial nerve.

Actions.—The *Quadratus labii superioris* raises the upper lip, and at the same time carries it a little forwards. Its angular head also acts as a dilatator of the

FIG. 520.—Scheme showing arrangement of fibres of *Orbicularis oris*.



nares; the infraorbital and zygomatic heads assist in forming the nasolabial furrow, which passes from the side of the nose to the upper lip and gives to the face an expression of sadness. When the whole muscle is in action it gives to the countenance an expression of contempt and disdain. The *Caninus* raises the angle of the mouth and assists the *Quadratus labii superioris* in producing the nasolabial furrow. The *Zygomaticus* draws the angle of the mouth backwards and upwards, as in laughing. The *Mentalis* raises and protrudes the lower lip, and at the same time wrinkles the skin of the chin, expressing doubt or disdain. The *Quadratus labii*

inferioris draws the lower lip directly downwards and a little lateralwards, as in the expression of irony. The *Triangularis* depresses the angle of the mouth, being the antagonist of the *Caninus* and *Zygomaticus*; acting with the *Caninus*, it will draw the angle of the mouth medialwards. The *Orbicularis oris* in its ordinary action effects the direct closure of the lips; by its deep, assisted by the oblique fibres, it closely applies the lips to the alveolar arches. The superficial part, consisting principally of the decussating fibres, brings the lips together and protrudes them. The *Buccinators* compress the cheeks, so that, during the process of mastication, the food is kept under the immediate pressure of the teeth. When the cheeks have been previously distended with air, the *Buccinator* muscles expel it from between the lips, as in blowing a trumpet; hence the name (*buccina*, a trumpet). The *Risorius* retracts the angle of the mouth, and produces an unpleasant grinning expression.

V. MUSCLES OF MASTICATION

Masseter.
Temporalis.

Pterygoideus externus.
Pterygoideus internus.

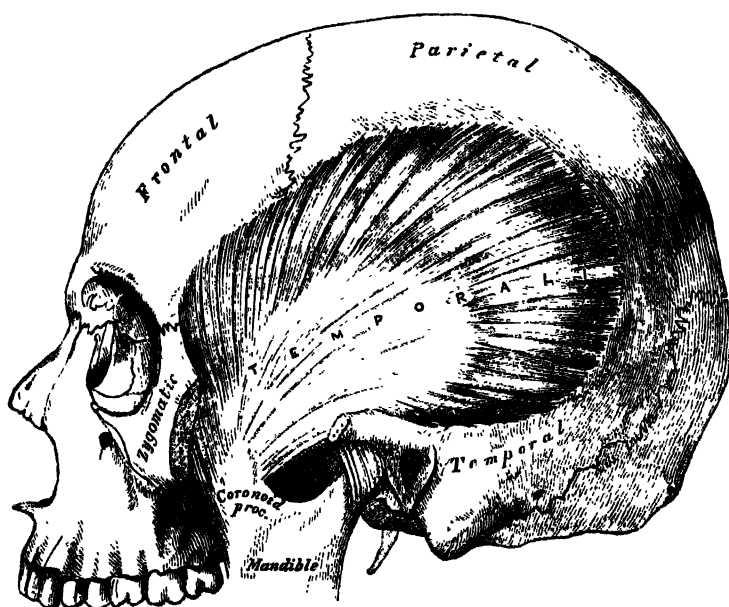
Covering the *Masseter*, and firmly connected with it, is a strong layer of fascia derived from the fascia colli and named the *parotideomasseteric fascia*. It is attached to the lower border of the zygomatic arch, and invests the parotid gland (p. 435).

The **Masseter** (fig. 517) is a quadrilateral muscle, consisting of two portions, superficial and deep. The *superficial portion*, the larger, arises by a thick aponeurosis from the zygomatic process of the maxilla, and from the anterior two-thirds of the lower border of the zygomatic arch; its fibres pass downwards and backwards, to be inserted into the angle and lower half of the lateral surface of the ramus of the mandible. The *deep portion* is much smaller and is partly concealed by the superficial portion; it arises from the posterior third of the lower border and from the whole of the medial surface of the zygomatic arch; its fibres pass downwards and forwards, to be inserted into the lateral surfaces of the coronoid process and the upper half of the ramus of the mandible.

Relations.—*Superficially* to the muscle are the integument, the Platysma, the Risorius, the Zygomaticus, and the parotid gland; the parotid duct, the branches of the facial nerve and the transverse facial vessels cross the muscle. The *deep surface* is in relation with the insertion of the Temporalis and the ramus of the mandible; a mass of fat separates it from the Buccinator muscle and nerve. The masseteric nerve and artery enter the muscle on its deep surface. The *posterior margin* is overlapped by the parotid gland; the *anterior* projects over the Buccinator and is crossed below by the anterior facial vein.

The **temporal fascia** covers the Temporalis. It is a strong, fibrous investment, covered, laterally, by the Auriculares anterior and superior, galea aponeurotica, and part of the Orbicularis oculi. The superficial temporal vessels and the auriculotemporal nerve cross it from below upwards. Above, it is a single

FIG. 521.—The Temporalis; the zygomatic arch and Masseter have been removed.



layer, attached to the entire extent of the superior temporal line; below, it consists of two layers, one of which is attached to the lateral, and the other to the medial border of the zygomatic arch. A small quantity of fat, the orbital branch of the superficial temporal artery, and the zygomaticotemporal branch of the maxillary nerve, are contained between these two layers. The deep surface of the fascia affords attachment to the superficial fibres of the Temporalis.

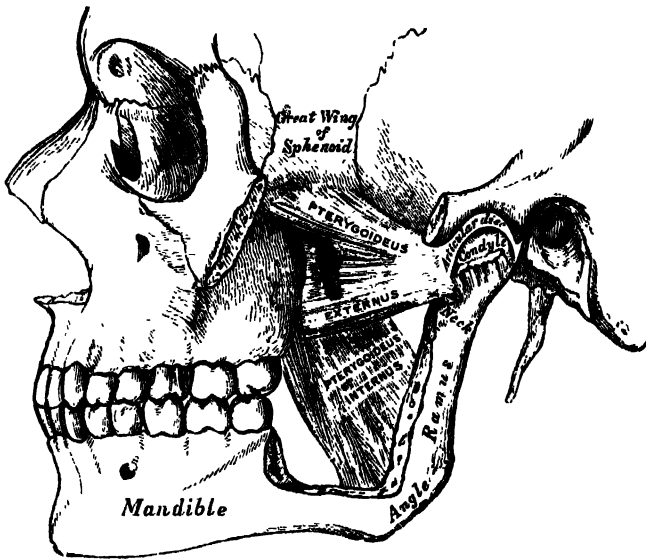
The **Temporalis** (fig. 521) is a fan-shaped muscle, situated at the side of the head. It arises from the whole of the temporal fossa (except that portion which is formed by the zygomatic bone) and from the deep surface of the temporal fascia. Its fibres converge as they descend, and end in a tendon which passes deep to the zygomatic arch and is inserted into the medial surface,

apex, and anterior border of the coronoid process, and the anterior border of the ramus of the mandible nearly as far forwards as the last molar tooth.

Relations.—*Superficially* to the muscle are the skin, the Auriculares anterior and superior, the temporal fascia, the superficial temporal vessels, the auriculotemporal nerve, the temporal branches of the facial nerve, the zygomaticotemporal nerve, the galea aponeurotica, the zygomatic arch, and the Masseter. The *deep surface* is in relation with the temporal fossa, the Pterygoideus externus and part of the Buccinator, the internal maxillary artery and its deep temporal branches, the deep temporal nerves, and the buccinator vessels and nerve. *Behind* the tendon of the muscle are the masseteric vessels and nerve. The *anterior border* is separated from the zygomatic bone by a mass of fat.

The **Pterygoideus externus** (fig. 522) is a short, thick, muscle, somewhat conical in form. It arises by two heads: an *upper* from the lower part of the lateral surface of the great wing of the sphenoid and from the infratemporal crest: and a *lower* from the lateral surface of the lateral pterygoid lamina.

FIG. 522.—The Pterygoidei; the zygomatic arch and a portion of the ramus of the mandible have been removed.



Its fibres pass horizontally backwards and lateralwards, to be inserted into a depression (pterygoid fovea) on the front of the neck of the condyle of the mandible, and into the anterior margin of the articular disc of the temporo-mandibular articulation.

Relations—Its *superficial surface* is in relation with the ramus of the mandible, the internal maxillary artery, which crosses it,* the tendon of the Temporalis, and the Masseter. Its *deep surface* rests against the upper part of the Pterygoideus internus, the sphenomandibular ligament, the middle meningeal artery, and the mandibular nerve; its *upper border* is in relation with the temporal and masseteric branches of the mandibular nerve; its *lower border* with the lingual and inferior alveolar nerves. The buccinator nerve and the internal maxillary artery pass between the heads of the muscle.

The **Pterygoideus internus** (fig. 522), a thick, quadrilateral muscle, arises from the medial surface of the lateral pterygoid lamina and the grooved surface of the pyramidal process of the palatine bone; it has a second slip of origin from the lateral surfaces of the pyramidal process of the palatine and tuberosity of the maxilla. Its fibres pass downwards, lateralwards, and backwards, and are inserted, by a strong tendinous lamina, into the lower and back part of the medial surfaces of the ramus and angle of the mandible, as high as the mandibular foramen.

* In many cases the artery lies deep to the muscle.

Relations.—The *lateral surface* of the muscle is, in relation with the ramus of the mandible, from which it is separated, at its upper part, by the Pterygoideus externus, the sphenomandibular ligament, the internal maxillary artery, the inferior alveolar vessels and nerve, the lingual nerve, and a process of the parotid gland. The *medial surface* is in relation with the Tensor veli palatini, and is separated from the Constrictor pharyngis superior by some areolar tissue.

Nerves.—The muscles of mastication are supplied by the mandibular nerve.

Actions.—The Temporalis, Masseter, and Pterygoideus internus raise the mandible against the maxillæ with great force. The Pterygoideus externus assists in opening the mouth by pulling forwards the condyle of the mandible and the articular disc, at the same time that the body of the mandible is depressed; but its main action is to protrude the mandible so that the inferior incisors are projected in front of the upper; in this action it is assisted by the Pterygoideus internus. The mandible is retracted by the posterior fibres of the Temporalis. If the Pterygoidei of one side act, the corresponding side of the mandible is drawn forward, while the opposite condyle remains comparatively fixed, and side-to-side movements, such as occur during the trituration of food, take place.

FASCIÆ AND MUSCLES OF THE ANTEROLATERAL REGION OF THE NECK

The anterolateral muscles of the neck may be arranged into the following groups:

- | | |
|--------------------------------------|--------------------------|
| I. Superficial and lateral cervical. | III. Anterior vertebral. |
| II. Supra- and infra-hyoid. | IV. Lateral vertebral. |

The **superficial fascia** of the neck is a thin lamina investing the Platysma, and is hardly demonstrable as a separate membrane.

The **fascia colli** (deep cervical fascia) (fig. 523) lies under cover of the Platysma, and invests the muscles of the neck; it also forms sheaths for the carotid vessels, and for the structures situated in front of the vertebral column.

The investing portion of the fascia is attached behind to the ligamentum nuchæ and to the spinous process of the seventh cervical vertebra. It forms a thin investment for the Trapezius, and from the anterior border of this muscle is continued forwards as a rather loose areolar layer, covering the posterior triangle of the neck, to the posterior border of the Sternocleidomastoideus, where it begins to assume the appearance of a fascial membrane. Along the hinder edge of the Sternocleidomastoideus it divides to enclose the muscle, and at the anterior margin again forms a single lamella, which covers the anterior triangle of the neck, and reaches forwards to the middle line, where it is continuous with the corresponding part from the opposite side of the neck. In the middle line of the neck it is fixed to the symphysis menti and the body of the hyoid bone.

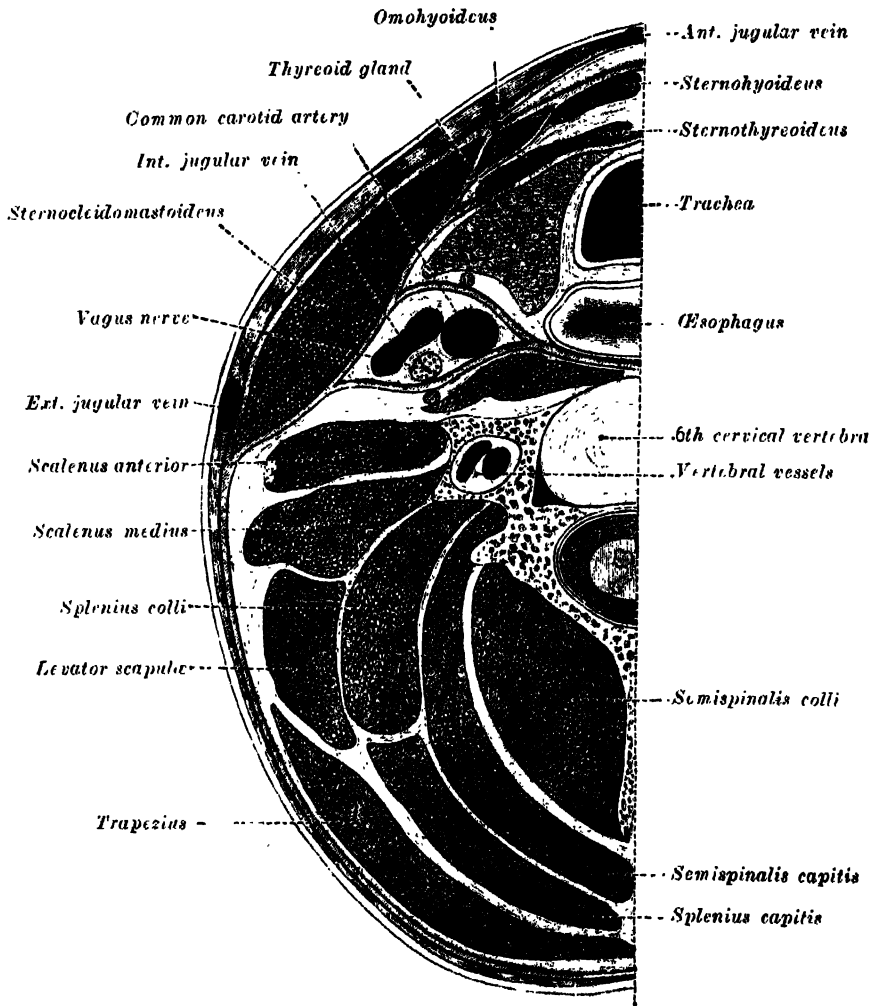
Above, the fascia is attached to the superior nuchal line of the occipital bone, to the mastoid process of the temporal bone, and to the whole length of the inferior border of the body of the mandible. Opposite the angle of the mandible it is very strong, and binds the anterior edge of the Sternocleidomastoideus firmly to that bone. Between the mandible and the mastoid process it ensheathes the parotid gland—the layer which covers the gland extends upwards under the name of the *parotidomasseteric fascia* and is fixed to the zygomatic arch. From the part which passes under the parotid gland a strong band ascends to the styloid process, forming the *stylomandibular ligament* (p. 347). Two other bands may be defined: the *sphenomandibular* (p. 347) and the *pterygospinous ligaments*. The *pterygospinous ligament* stretches from the upper part of the posterior border of the lateral pterygoid lamina to the spinous process of the sphenoid. It occasionally ossifies, and in such cases, between its upper border and the base of the skull, a foramen is formed which transmits the branches of the mandibular nerve to the muscles of mastication.

Below, the fascia is attached to the acromion, the clavicle, and the manubrium sterni. Some little distance above the last, it splits into a superficial and a deep layer. The former is attached to the anterior border of the manubrium

the latter to its posterior border and to the interclavicular ligament. Between these two layers is a slit-like interval, the *suprasternal space*, or *space of Burns*; it contains a small quantity of areolar tissue, the lower portions of the anterior jugular veins and their transverse connecting branch, the sternal heads of the Sternocleidomastoidei, and sometimes a lymph-gland.

The fascia which lines the deep surface of the Sternocleidomastoideus gives off the following processes: (1) A process envelops the tendon of the Omo-

FIG. 523.—Section of the neck at about the level of the sixth cervical vertebra, showing the arrangement of the fascia colli.



hyoideus, and binds it down to the sternum and first costal cartilage. (2) The *carotid sheath* encloses the carotid artery, internal jugular vein, and vagus nerve. (3) The *prevertebral fascia* extends medialwards behind the carotid vessels, where it assists in forming their sheath, and passes in front of the prevertebral muscles. It forms the posterior wall of a fibrous compartment which contains the larynx and trachea, the thyroid gland, and the pharynx and oesophagus. The prevertebral fascia is fixed above to the base of the skull, and below is continued into the thorax in front of the Longus colli muscles. Parallel to the carotid sheath and along its medial aspect the prevertebral fascia gives off a thin lamina, the *buccopharyngeal fascia*, which closely invests the Constrictor

muscles of the pharynx, and is continued forward from the Constrictor pharyngis superior on to the Buccinator. It is attached to the prevertebral layer by loose connective tissue only, and thus an easily distended space, the *retropharyngeal space*, is found between them. This space is limited above by the base of the skull; below it extends behind the œsophagus into the posterior mediastinal cavity of the thorax. The prevertebral fascia is prolonged downwards and lateralwards behind the carotid vessels and in front of the Scaleri, and forms a sheath for the brachial nerves and subclavian vessels in the posterior triangle of the neck; it is continued under the clavicle as the axillary sheath and is attached to the deep surface of the coracoclavicular fascia. Immediately above and behind the clavicle an areolar space exists between the investing layer and the sheath of the subclavian vessels, and in this space are found the lower part of the external jugular vein, the supraclavicular nerves, the transverse scapular and transverse cervical vessels, and the inferior belly of the Omohyoideus muscle. This space is limited below by the fusion of the coracoclavicular fascia with the anterior wall of the axillary sheath. (4) The *pretracheal fascia* extends medialwards in front of the carotid vessels, and assists in forming the carotid sheath. It is continued behind the infrahyoid muscles, and, after enveloping the thyroid gland, is prolonged in front of the trachea to meet the corresponding layer of the opposite side. Above, it is fixed to the hyoid bone, while below, it is carried downwards in front of the trachea and large vessels at the root of the neck, and ultimately blends with the fibrous pericardium. This layer is fused on either side with the prevertebral fascia, and with it completes the compartment containing the larynx and trachea, the thyroid gland, and the pharynx and œsophagus.*

Applied Anatomy.—The fascia colli (deep cervical fascia) is of considerable importance from a surgical point of view. The investing layer opposes the extension of abscesses towards the surface, and pus forming beneath it has a tendency to extend lateralwards. If the pus be contained in the anterior triangle, it may find its way into the anterior mediastinal cavity, in front of the pretracheal layer of fascia; but owing to the thinness of the fascia in this situation it more frequently finds its way to the surface and points above the sternum. Pus forming under cover of the pretracheal layer would in all probability find its way into the posterior mediastinal cavity. Pus forming behind the prevertebral layer, in cases, for instance, of caries of the bodies of the cervical vertebrae, may extend towards the lateral part of the neck and point in the posterior triangle, or may perforate this layer of fascia and the buccopharyngeal fascia and point into the pharynx (retropharyngeal abscess).

In cases of cut throat, when the wound involves only the investing layer the injury is usually trivial, the special danger being injury to the external jugular vein, and the special complication, diffuse cellulitis. But where the second of the two layers is opened up, important structures may be injured, and serious results follow.

The sternal head of origin of the Sternocleidomastoideus is contained in the supra-sternal space, so that this space is opened in division of this tendon. The lower part of the anterior jugular vein is also contained in the same space.

I. SUPERFICIAL AND LATERAL CERVICAL MUSCLES

Platysma. Trapezius. Sternocleidomastoideus.

The **Platysma** (fig. 517) is a broad sheet arising from the fascia covering the upper parts of the Pectoralis major and Deltoides; its fibres cross the clavicle, and proceed obliquely upwards and medialwards along the side of the neck. The anterior fibres interlace, below and behind the symphysis menti, with the fibres of the muscle of the opposite side; the posterior fibres cross the mandible, some being inserted into the bone below the oblique line, others into the skin and subcutaneous tissue of the lower part of the face, many of these fibres blending with the muscles about the angle and lower part of the mouth. Sometimes fibres can be traced to the Zygomaticus, or to the margin of the Orbicularis oculi. Beneath the Platysma, the external jugular vein descends from the angle of the mandible to the clavicle.

* F. G. Parsons (*Journal of Anatomy and Physiology*, vol. xlv.) regards the carotid sheath and the fascial planes in the neck as structures which are artificially produced by dissection.

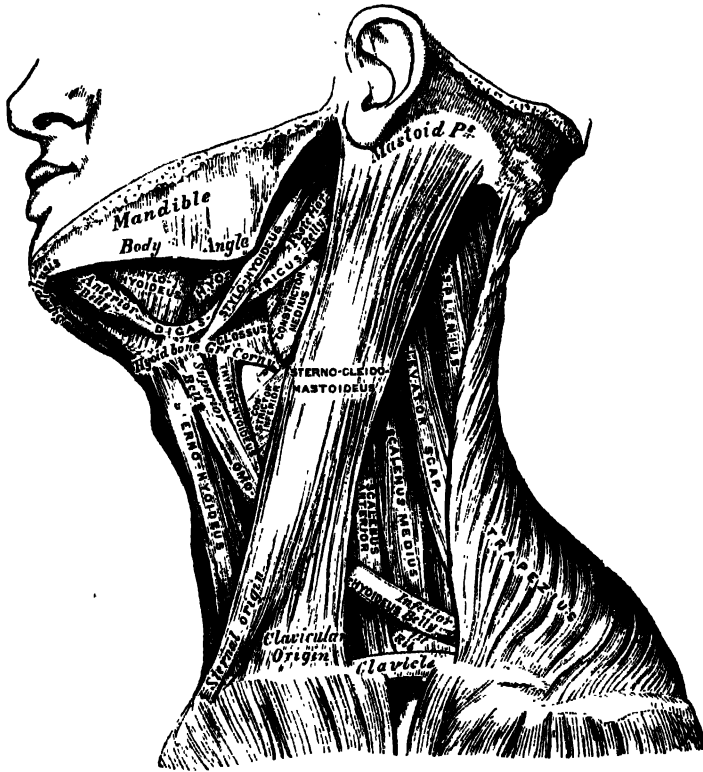
Actions.—When the entire *Platysma* is in action it produces a wrinkling of the surface of the skin of the neck in an oblique direction. Its anterior portion, the thickest part of the muscle, depresses the mandible; it also serves to draw down the lower lip and angle of the mouth in the expression of melancholy.

Nerve.—The *Platysma* is supplied by the cervical branch of the facial nerve.

The *Trapezius* is described on p. 478.

The *Sternocleidomastoideus* (fig 524) passes obliquely across the side of the neck. It is thick and narrow at its central part, but broader and thinner at either end. It arises by two heads. The *medial* or *sternal* head is a rounded tendinous fasciculus, which arises from the upper part of the anterior surface of the manubrium sterni, and is directed upwards, lateralwards, and backwards. The *lateral* or *clavicular* head, composed of fleshy and aponeurotic fibres, arises

FIG. 524.—Muscles of the neck. Lateral view.



from the superior border and anterior surface of the medial third of the clavicle, and is directed almost vertically upwards. The two heads are separated from one another at their origins by a triangular interval, but gradually blend, below the middle of the neck, into a thick, rounded belly. The muscle is inserted, by a strong tendon, into the lateral surface of the mastoid process, from its apex to its superior border, and by a thin aponeurosis into the lateral half of the superior nuchal line of the occipital bone.

The *Sternocleidomastoideus* varies much in its extent of origin from the clavicle: in some cases the clavicular may be as narrow as the sternal head; in others, as much as 7.5 cm. in breadth. When the clavicular origin is broad, it is occasionally subdivided into several slips. More rarely, the adjoining margins of the *Sternocleidomastoideus* and *Trapezius* are in contact.

This muscle divides the quadrilateral area of the side of the neck into two triangles, an anterior and a posterior. The boundaries of the *anterior triangle* are, in front, the median line of the neck; above, the lower border of the body of the mandible, and an imaginary line drawn from the angle of the mandible to the *Sternocleidomastoideus*; behind, the anterior border of the *Sternocleidomastoideus*.

The apex of the triangle is at the upper border of the sternum. The boundaries of the *posterior triangle* are, in front, the posterior border of the Sternocleidomastoideus; below, the middle third of the clavicle; behind, the anterior margin of the Trapezius. The apex corresponds with the meeting of the Sternocleidomastoideus and Trapezius on the occipital bone.

Relations.—*Superficially* to the muscle are the integument and Platysma; it is separated from the Platysma by the external jugular vein, the great auricular and cervical cutaneous nerves, and the investing layer of the deep cervical fascia. The *deep surface* is in relation with the sternoclavicular articulation, the process of the deep cervical fascia which binds the inferior belly of the Omohyoideus to the sternum and clavicle, the Sternohyoideus, Sternothyroideus, Omohyoideus, posterior belly of the Digastricus, Levator scapulæ, Splenius and Scaleri muscles, the common carotid artery, the internal and anterior jugular veins, the origins of the internal and external carotid arteries, the occipital, subclavian, transverse cervical, and transverse scapular arteries and veins, the phrenic, vagus, hypoglossal, descendens and communicantes hypoglossi nerves, the accessory nerve which pierces its upper third, the cervical plexus, the upper part of the brachial plexus, parts of the thyroid and parotid glands and their vessels, and the deep cervical lymph-glands.

Nerves.—The Sternocleidomastoideus is supplied by the accessory nerve and branches from the anterior divisions of the second and third cervical nerves.

Actions.—When one Sternocleidomastoideus acts, it draws the head towards the shoulder of the same side, assisted by the Splenius and the Obliquus capitis inferior of the opposite side; it also rotates the head so as to carry the face towards the opposite side. Acting together from their sternoclavicular attachments the two muscles will flex the cervical part of the vertebral column; if the head be fixed they will assist in elevating the thorax in forced inspiration.

Applied Anatomy.—The surgical anatomy of the Sternocleidomastoideus is of importance in connexion with the deformity known as *wry-neck*, which is due to a contracted condition of this muscle. The wry-neck may be temporary, as the result of direct irritation of the muscle or of the nerves supplying it, and may occur in acute glandular enlargement, cellulitis of the neck, myositis of the muscle, or cervical caries. It may, however, be permanent, and is then most often due to injury to the muscle during birth, especially in breech presentations, rupture of the fibres and subsequent cicatricial contraction taking place. In these cases, division of the muscle is often necessary to effect a cure, and this may be done either subcutaneously or through an open wound. The open method is, however, much to be preferred, as being the more effectual and the less dangerous, if precautions are taken to keep the wound aseptic. The tendons of origin are freely exposed by a horizontal incision across the root of the neck and carefully divided; any tense bands of fascia which exist should also be divided. The wound is now sutured and dressed, and the head fixed in as straight a position as possible.

There is also a condition coming on in adult life (spasmodic torticollis), which is a very distressing form of functional nervous disease. It begins with tonic or clonic spasm of one Sternocleidomastoideus, which is soon followed by spasm of the Trapezius, particularly its clavicular portion. The Splenius of the opposite side, the Scaleri, Semispinales capitis, and Longissimi capitis may all become involved in turn, with secondary contracture of the deep cervical fascia. Operation in these cases often fails to give satisfactory results. Tenotomy of the affected muscles or section of the nerves supplying them may afford temporary relief, but the spasm often returns when the cut nerves or muscles rejoin.

II. SUPRA- AND INFRA-HYOID MUSCLES (figs. 524, 525)

The suprahyoid muscles are :

Digastricus.
Stylohyoideus.

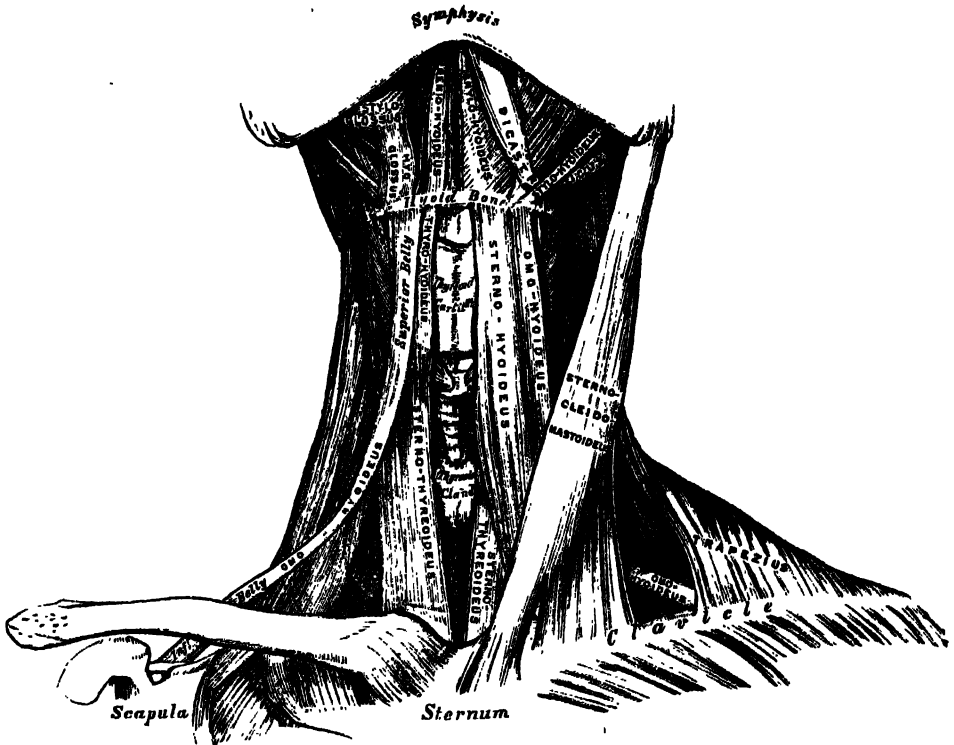
Mylohyoideus.
Geniohyoideus.

The **Digastricus** consists of two fleshy bellies united by an intermediate rounded tendon. It lies below the body of the mandible, and extends, in a curved form, from the mastoid process to the chin. The *posterior belly*, longer than the anterior, arises from the mastoid notch (digastric fossa) of the temporal bone and passes downwards and forwards. The *anterior belly* arises from a depression on the inner side of the lower border of the body of the mandible, close to the middle line, and passes downwards and backwards. The two bellies

end in an intermediate tendon which perforates the Stylohyoideus muscle, and is held in connexion with the side of the body and the greater cornu of the hyoid bone by a fibrous loop, which is sometimes lined by a mucous sheath. An aponeurotic layer is given off from the tendon of the Digastricus on either side of the neck, to be attached to the body and greater cornua of the hyoid bone; this is termed the *suprahyoid aponeurosis*.

Relations.—Its *superficial surface* is in relation with the Platysma, Sternocleidomastoideus, part of the Splenius, Longissimus capitis, mastoid process, Stylohyoideus, and the parotid gland. The *deep surface* of the anterior belly lies on the Mylohyoideus: that of the posterior belly on the Styloglossus, Stylopharyngeus, and Hyoglossus, the external carotid artery and its occipital, lingual, external maxillary, and ascending pharyngeal branches, the internal carotid artery, internal jugular vein, and hypoglossal nerve.

FIG. 525.—Muscles of the neck. Anterior view.



The Digastricus divides the upper part of the anterior triangle of the neck into three triangles: (1) the *submaxillary triangle*, bounded above by the lower border of the mandible and a line drawn from its angle to the Sternocleidomastoideus, below by the posterior belly of the Digastricus and the Stylohyoideus, in front by the anterior belly of the Digastricus; (2) the *carotid triangle*, bounded above by the posterior belly of the Digastricus and Stylohyoideus, behind by the Sternocleidomastoideus, below by the Omohyoideus; (3) the *suprahyoid or submental triangle*, bounded laterally by the anterior belly of the Digastricus, medially by the middle line of the neck from the hyoid bone to the symphysis menti, and inferiorly by the body of the hyoid bone.

The **Stylohyoideus** is a slender muscle, lying in front of, and above, the posterior belly of the Digastricus. It arises from the posterior and lateral surfaces of the styloid process, near the base; and, passing downwards and forwards, is inserted into the body of the hyoid bone, at its junction with the greater cornu, and just above the Omohyoideus. It is perforated, near its insertion, by the tendon of the Digastricus.

The *stylohyoid ligament*.—In connexion with the Stylohyoideus muscle a ligamentous band, the *stylohyoid ligament*, may be described. It is a fibrous cord, which is attached to the tip of the styloid process of the temporal bone and the lesser cornu of the hyoid bone. It frequently contains a little cartilage in its centre, is often partially ossified, and in many animals forms a distinct bone, the *epihyal*.

The *Mylohyoideus*, flat and triangular, is situated immediately above the anterior belly of the Digastricus, and forms, with its fellow of the opposite side, a muscular floor for the cavity of the mouth. It arises from the whole length of the mylohyoid line of the mandible. The posterior fibres pass medialwards and slightly downwards, to be inserted into the front of the body of the hyoid bone near its lower border. The middle and anterior fibres are inserted into a median fibrous raphe extending from the symphysis menti to the hyoid bone, where they join at an angle with the fibres of the opposite muscle. This median raphe is sometimes wanting; the fibres of the two muscles are then continuous.

Relations.—Its *superficial or inferior surface* is in relation with the Platysma, the anterior belly of the Digastricus, the suprahyoid aponeurosis, the superficial part of the submaxillary gland, the external maxillary and submental vessels, and the mylohyoid vessels and nerve. Its *deep or superior surface* is in relation with the Geniohyoideus, part of the Hyoglossus, and the Styloglossus, the hypoglossal and lingual nerves, the submaxillary ganglion, the sublingual gland, the deep portion of the submaxillary gland and the submaxillary duct, the lingual and sublingual vessels, and the buccal mucous membrane.

The *Geniohyoideus* is a narrow muscle, situated above the medial part of the Mylohyoideus. It arises from the inferior mental spine on the back of the symphysis menti, and runs backwards and slightly downwards, to be inserted into the anterior surface of the body of the hyoid bone; it is in contact with its fellow of the opposite side.

Nerves.—The Mylohyoideus and anterior belly of the Digastricus are supplied by the mylohyoid branch of the inferior alveolar nerve; the Stylohyoideus and posterior belly of the Digastricus, by the facial; the Geniohyoideus, by the first cervical nerve through the hypoglossal.

Actions.—These muscles perform two very important actions. During the act of deglutition they raise the hyoid bone, and with it the base of the tongue; when the hyoid bone is fixed by its depressors and those of the larynx, they depress the mandible. During the first act of deglutition, when the mass of food is being driven from the mouth into the pharynx, the hyoid bone (and with it the tongue) is carried upwards and forwards by the anterior bellies of the Digastrici, the Mylohyoidei, and Geniohyoidei. In the second act, when the mass is passing through the pharynx, the direct elevation of the hyoid bone takes place by the combined action of all the muscles; and after the food has passed, the hyoid bone is carried upwards and backwards by the posterior bellies of the Digastrici and the Stylohyoidei, which assist in preventing the return of the food into the mouth.

The infrahyoid muscles are :

Sternohyoideus.
Sternothyreoideus.

Thyreohyoideus.
Omohyoideus.

The *Sternohyoideus*, a thin, narrow muscle, arises from the posterior surface of the medial end of the clavicle, the capsule of the sternoclavicular joint, and the upper and posterior part of the manubrium sterni. Passing upwards and medialwards, it is inserted, by short tendinous fibres, into the lower border of the body of the hyoid bone. It sometimes presents, immediately above its origin, a transverse tendinous inscription. Below, the Sternohyoideus is separated from its fellow by a considerable interval; but the two muscles come into contact with one another in the middle of their course, and, from this upwards, lie side by side.

The *Sternothyreoideus* is shorter and wider than the preceding muscle, and lies under cover of it. It arises from the posterior surface of the manubrium sterni, below the origin of the Sternohyoideus, and from the edge of the cartilage of the first, and sometimes that of the second, rib; it is inserted

into the oblique line on the lamina of the thyroid cartilage. This muscle is in close contact with its fellow at the lower part of the neck, but diverges somewhat as it ascends; it is occasionally traversed by a transverse or oblique tendinous inscription.

The **Thyreohyoideus**, a small, quadrilateral muscle, may be looked upon as an upward continuation of the Sternothyroideus. It arises from the oblique line on the lamina of the thyroid cartilage, and is inserted into the lower border of the greater cornu of the hyoid bone.

The **Omohyoideus** consists of two fleshy bellies united by a central tendon. It arises from the upper border of the scapula, and occasionally from the superior transverse ligament which crosses the scapular notch, its extent of attachment to the scapula varying from a few millimetres to 2.5 cm. From this origin, the *inferior belly* forms a flat, narrow fasciculus, which inclines forwards and slightly upwards across the lower part of the neck, being bound to the clavicle by a fibrous expansion; it then passes behind the Sternocleidomastoideus, becomes tendinous and changes its direction, forming an obtuse angle. It ends in the *superior belly*, which passes almost vertically upwards close to the lateral border of the Sternohyoideus, and is inserted into the lower border of the body of the hyoid bone, lateral to the insertion of the Sternohyoideus. The central tendon of this muscle varies in length and form, and is held in position by a process of the deep cervical fascia, which ensheathes it and is prolonged down to be attached to the clavicle and first rib; it is by this means that the angular form of the muscle is maintained.

The inferior belly of the Omohyoideus divides the posterior triangle of the neck into an upper or *occipital* and a lower or *subclavian* triangle, while its superior belly divides the anterior triangle into an upper or *carotid* and a lower or *muscular* triangle.

Nerves.—The Thyreohyoideus is supplied by a branch from the hypoglossal nerve; the superior belly of the Omohyoideus by the descendens hypoglossi; the Sternohyoideus, Sternothyroideus, and inferior belly of the Omohyoideus are supplied by branches from a loop (ansa hypoglossi) between the descendens hypoglossi and the communicantes cervicales.

Actions.—These muscles depress the larynx and hyoid bone, after they have been drawn up with the pharynx in the act of deglutition. The Omohyoidei not only depress the hyoid bone, but carry it backwards and to one or the other side. They are concerned also in prolonged inspiratory efforts; for by rendering the lower part of the cervical fascia tense they lessen the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs. The Thyreohyoideus may act as an elevator of the thyroid cartilage, drawing the cartilage up behind the hyoid bone. The Sternothyroideus acts as a depressor of the thyroid cartilage.

III. ANTERIOR VERTEBRAL MUSCLES (fig. 526)

Longus colli.
Longus capitis.

Rectus capitis anterior.
Rectus capitis lateralis.

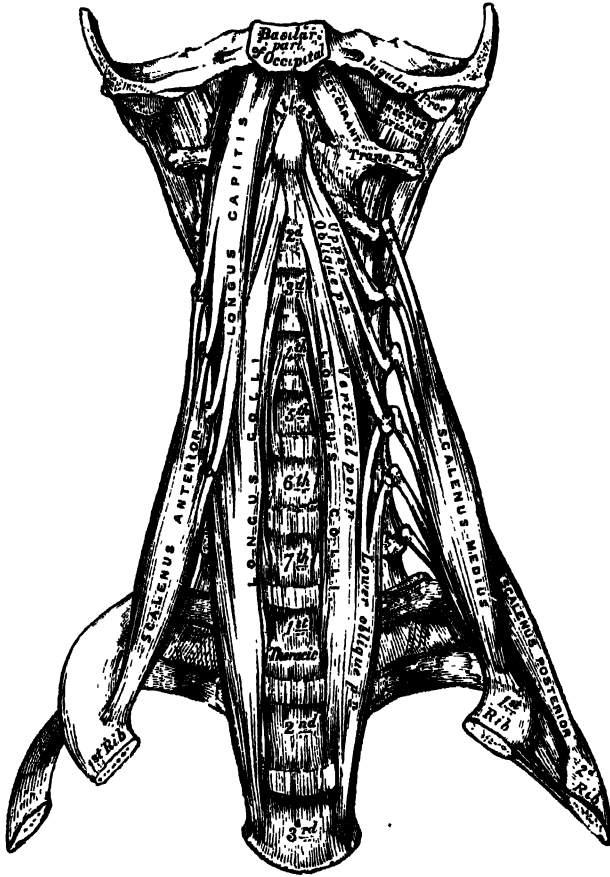
The **Longus colli** is situated on the anterior surface of the vertebral column, between the atlas and the third thoracic vertebra. It is divisible into three portions, a superior oblique, an inferior oblique, and a vertical; its origin and insertion consist of tendinous slips. The *superior oblique portion* arises from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebrae; it is directed upwards and medialwards, and is inserted by a narrow tendon into the tubercle on the anterior arch of the atlas. The *inferior oblique portion*, the smallest part of the muscle, arises from the front of the bodies of the first two or three thoracic vertebrae; it runs upwards and lateralwards, and is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebrae. The *vertical portion* arises from the front of the bodies of the upper three thoracic and lower three cervical vertebrae, and is inserted into the front of the bodies of the second, third, and fourth cervical vertebrae.

The **Longus capitis** (*Rectus capitis anticus major*), broad and thick above, narrow below, arises by tendinous slips, from the anterior tubercles of the

transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and is inserted into the inferior surface of the basilar part of the occipital bone.

The **Rectus capitis anterior** (*Rectus capitis anticus minor*) is a short, flat muscle, situated behind the upper part of the *Longus capitis*. It arises from the anterior surface of the lateral mass of the atlas, and from the root of its transverse process, and is inserted into the inferior surface of the basilar part of the occipital bone in front of the occipital condyle.

FIG. 526.—The anterior and lateral vertebral muscles.



The **Rectus capitis lateralis**, a short, flat muscle, arises from the upper surface of the transverse process of the atlas, and is inserted into the under surface of the jugular process of the occipital bone.

Nerves.—These muscles receive their nerve-supply from the anterior divisions of the cervical nerves; the *Rectus capitis anterior* and the *Rectus capitis lateralis* from the loop between the first and second cervical; the *Longus capitis*, by branches from the first, second, and third cervical; the *Longus colli*, by branches from the second to the seventh cervical inclusive.

Actions.—The *Longus capitis* and *Rectus capitis anterior* are the direct antagonists of the muscles at the back of the neck, and serve to restore the head to its natural position after it has been drawn backwards. These muscles also flex the head, and, from their obliquity, rotate it, so as to turn the face to one or the other side. The *Rectus lateralis*, acting on one side, bends the head laterally. The *Longus colli* flexes and slightly rotates the cervical portion of the vertebral column.

IV. LATERAL VERTEBRAL MUSCLES (fig. 526)

Scalenus anterior.

Scalenus medius.

Scalenus posterior.

The **Scalenus anterior** lies deeply at the side of the neck, behind the Sternocleidomastoideus. It arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descending, almost vertically, is inserted by a narrow, flat tendon into the scalene tubercle on the inner border of the first rib, and into the ridge on the upper surface of the rib in front of the subclavian groove.

Relations.—In front of it are the clavicle, the Subclavius, Sternocleidomastoideus, and Omohyoideus muscles, the transverse cervical, transverse scapular and ascending cervical arteries, the subclavian vein, and the phrenic nerve. Its *posterior surface* is in relation with the cords of the brachial plexus, the subclavian artery, and the pleura, which separate it from the Scalenus medius. Below, it is separated from the Longus colli by the vertebral artery, and above, from the Longus capitis by the ascending cervical branch of the inferior thyroid artery.

The **Scalenus medius**, the largest and longest of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower six cervical vertebræ, and descending along the side of the vertebral column, is inserted by a broad attachment into the upper surface of the first rib, between the tubercle and the subclavian groove.

Relations.—Its *anterior surface* is in relation with the Sternocleidomastoideus; it is crossed by the clavicle and the Omohyoideus; the subclavian artery and the cervical nerves separate it from the Scalenus anterior. *Lateral* to it are the Levator scapulæ and the Scalenus posterior. The long thoracic nerve is formed in the substance of the muscle and emerges from it; the dorsal scapular nerve pierces it.

The **Scalenus posterior**, the smallest and most deeply seated of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower two or three cervical vertebræ, and is inserted by a thin tendon into the outer surface of the second rib, behind the attachment of the Serratus anterior. It is occasionally blended with the Scalenus medius.

Nerves.—The Scaleni are supplied by branches from the second to the seventh cervical nerves.

Actions.—When the Scaleni act from above, they elevate the first and second ribs, and are, therefore, inspiratory muscles. Acting from below, they bend the vertebral column to one or other side; if the muscles of both sides act, the vertebral column is lightly flexed.

FASCIÆ AND MUSCLES OF THE TRUNK

The muscles of the trunk may be arranged in six groups:

- | | |
|------------------------------|------------------------------|
| I. Deep muscles of the back. | IV. Muscles of the abdomen. |
| II. Suboccipital muscles. | V. Muscles of the pelvis. |
| III. Muscles of the thorax. | VI. Muscles of the perinæum. |

I. DEEP MUSCLES OF THE BACK (fig. 528)

The deep or intrinsic muscles of the back consist of a complex group of muscles extending from the pelvis to the skull. They are:

Splenius capitis.
Splenius cervicis.
Sacrospinalis.
Semispinalis.

Multifidus.
Rotatores.
Interspinales.
Intertransversarii.

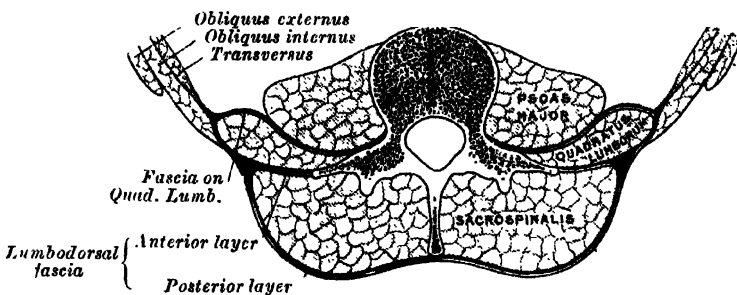
The **lumbodorsal fascia** covers the deep muscles of the back of the trunk. Above, it passes in front of the Serratus posterior superior and is continuous with the *nuchal fascia*, a similar investing layer on the back of the neck.

In the thoracic region the lumbodorsal fascia is a thin fibrous lamina covering the extensor muscles of the vertebral column and separating them from the muscles connecting the vertebral column to the upper extremity. It contains both longitudinal and transverse fibres, and is attached, *medially*, to the spinous processes of the thoracic vertebræ; *laterally*, to the angles of the ribs.

In the lumbar region the lumbodorsal fascia (lumbar aponeurosis) is in two layers, anterior and posterior (fig. 527). The posterior layer is attached to the spinous processes of the lumbar and sacral vertebræ and to the supraspinal ligament; the anterior is attached, *medially*, to the tips of the transverse processes of the lumbar vertebræ, and to the intertransverse ligaments, *below*, to the iliolumbar ligament, and *above*, to the lumbocostal ligament (p. 360). The two layers unite at the lateral margin of the Sacrospinalis, to form the tendon of origin of the Transversus abdominis.

The **Splenius capitis** (fig. 547) arises from the lower half of the ligamentum nuchæ, from the spinous process of the seventh cervical vertebra, and from the spinous processes of the upper three or four thoracic vertebræ. The fibres of the muscle are directed upwards and lateralwards and are inserted, under cover of the Sternocleidomastoideus, into the mastoid process of the temporal

FIG. 527.—Diagram of a transverse section of the posterior abdominal wall, to show the disposition of the lumbodorsal fascia.



bone, and into the rough surface on the occipital bone just below the lateral third of the superior nuchal line.

The **Splenius cervicis** (fig. 547) arises from the spinous processes of the third to the sixth thoracic vertebræ: it is inserted into the posterior tubercles of the transverse processes of the upper two or three cervical vertebræ.

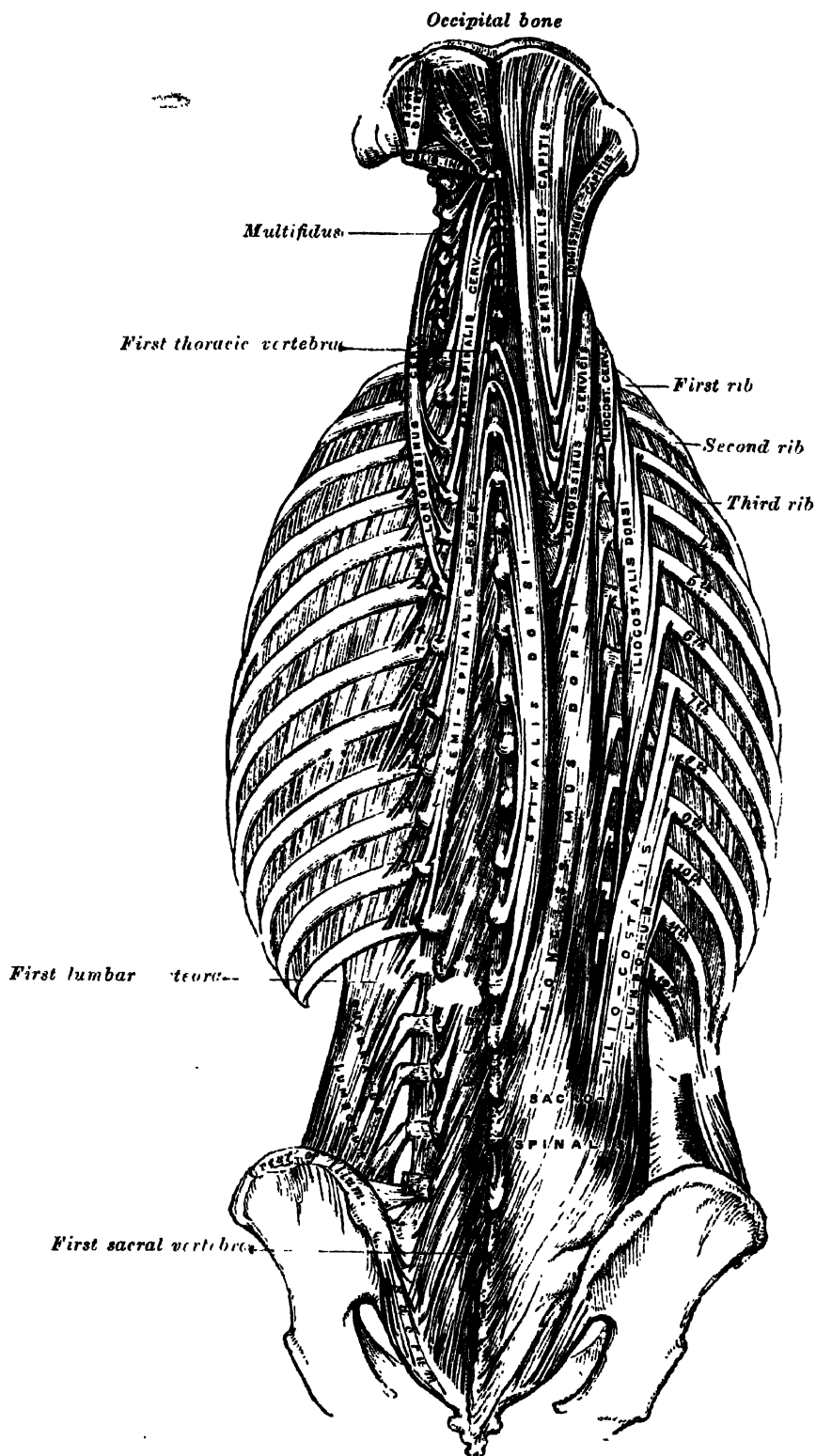
Nerves.—The Splenii are supplied by the lateral branches of the posterior divisions of the middle and lower cervical nerves.

Actions.—The Splenii of the two sides, acting together, draw the head directly backwards, assisting the Trapezius and Semispinalis capitis; acting separately, they draw the head to one side, and slightly rotate it, turning the face to the same side. They also assist in supporting the head in the erect position.

The **Sacrospinalis** (fig. 528), and its prolongations in the thoracic and cervical regions, lie in the groove on the side of the vertebral column. They are covered in the lumbar and thoracic regions by the lumbodorsal fascia, and in the cervical region by the nuchal fascia. They form a large muscular and tendinous mass which varies in size and structure at different parts of the vertebral column. In the sacral region it is narrow and pointed, and at its origin chiefly tendinous in structure. In the lumbar region it is larger, and forms a thick fleshy mass which, on being followed upwards, is subdivided into three columns; these gradually diminish in size as they ascend to be inserted into the vertebræ and ribs.

The Sacrospinalis arises from the anterior surface of a broad and thick tendon, which is attached to the middle sacral crest, to the spinous processes of the lumbar and the eleventh and twelfth thoracic vertebræ, to the supraspinal ligament, to the posterior part of the inner lip of the iliac crest and to the lateral crest of the sacrum, where it blends with the sacrotuberous and posterior sacro-iliac ligaments; some of its fibres are continuous with the

FIG. 528.—Deep muscles of the Back.



fibres of origin of the *Glutæus maximus*. The muscular fibres form a large fleshy mass which splits in the upper lumbar region into three columns, viz. a lateral, the *Iliocostalis*, an intermediate, the *Longissimus*, and a medial, the *Spinalis*. Each of these consists, from below upwards, of three parts, as follows :

<i>Lateral Column.</i>	<i>Intermediate Column.</i>	<i>Medial Column.</i>
<i>Iliocostalis.</i>	<i>Longissimus.</i>	<i>Spinalis.</i>
(a) <i>I. lumborum.</i>	(a) <i>L. dorsi.</i>	(a) <i>S. dorsi.</i>
(b) <i>I. dorsi.</i>	(b) <i>L. cervicis.</i>	(b) <i>S. cervicis.</i>
(c) <i>I. cervicis.</i>	(c) <i>L. capitis.</i>	(c) <i>S. capitis.</i>

The *Iliocostalis lumborum* is inserted, by flattened tendons, into the inferior borders of the angles of the lower six or seven ribs.

The *Iliocostalis dorsi* (*Musculus accessorius*) arises from the upper borders of the angles of the lower six ribs medially to the tendons of insertion of the *Iliocostalis lumborum*; it is inserted into the upper borders of the angles of the upper six ribs and into the back of the transverse process of the seventh cervical vertebra.

The *Iliocostalis cervicis* (*Cervicalis ascendens*) arises from the angles of the third, fourth, fifth, and sixth ribs, and is inserted into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebrae.

The *Longissimus dorsi* is the intermediate and largest of the continuations of the *Sacrospinalis*. In the lumbar region, where it is as yet blended with the *Iliocostalis lumborum*, some of its fibres are attached to the whole length of the posterior surfaces of the transverse processes and the accessory processes of the lumbar vertebrae, and to the anterior layer of the lumbodorsal fascia. In the thoracic region it is inserted, by rounded tendons, into the tips of the transverse processes of all the thoracic vertebrae, and by fleshy processes into the lower nine or ten ribs between their tubercles and angles.

The *Longissimus cervicis* (*Transversarius cervicis*), situated medially to the *Longissimus dorsi*, arises by long thin tendons from the summits of the transverse processes of the upper four or five thoracic vertebrae, and is inserted by similar tendons into the posterior tubercles of the transverse processes of the cervical vertebrae from the second to the sixth inclusive.

The *Longissimus capitis* (*Trachelomastoides*) lies between the *Longissimus cervicis* and the *Semispinalis capitis*. It arises by tendons from the transverse processes of the upper four or five thoracic vertebrae, and the articular processes of the lower three or four cervical vertebrae, and is inserted into the posterior margin of the mastoid process, beneath the *Splenius capitis* and *Sternocleidomastoideus*. It is usually crossed by a tendinous inscription near its insertion.

The *Spinalis dorsi*, the medial continuation of the *Sacrospinalis*, is scarcely separable as a distinct muscle. It is situated at the medial side of the *Longissimus dorsi*, and is intimately blended with it; it arises by three or four tendons from the spinous processes of the first lumbar and the last two thoracic vertebrae: these, uniting, form a small muscle which is inserted by separate tendons into the spinous processes of the upper thoracic vertebrae, the number varying from four to eight. It is intimately united with the *Semispinalis dorsi*, situated beneath it.

The *Spinalis cervicis* is an inconstant muscle, which arises from the lower part of the ligamentum nuchae, the spinous process of the seventh cervical, and sometimes from the spinous processes of the first and second thoracic vertebrae, and is inserted into the spinous process of the epistropheus, and occasionally into the spinous processes of the two vertebrae below it.

The *Spinalis capitis* is usually inseparably connected with the *Semispinalis capitis* (p. 448).

The *Semispinalis dorsi* consists of thin, fleshy fasciculi, interposed between tendons of considerable length. It arises by a series of small tendons from the transverse processes of the sixth to the tenth thoracic vertebrae, and is inserted, by tendons, into the spinous processes of the upper four thoracic and lower two cervical vertebrae.

The *Semispinalis cervicis*, thicker than the preceding, arises by a series of tendinous and fleshy fibres from the transverse processes of the upper five or

six thoracic vertebræ, and is inserted into the cervical spinous processes; from the epistropheus to the fifth inclusive. The fasciculus connected with the epistropheus is the largest, and is chiefly muscular in structure.

The **Semispinalis capitis** (Complexus) is situated at the back part of the neck, beneath the Splenius, and medial to the Longissimi cervicis and capitis. It arises by a series of tendons from the tips of the transverse processes of the upper six or seven thoracic and the seventh cervical vertebræ, and from the articular processes of the fourth, fifth, and sixth cervical vertebræ. The tendons are succeeded by a broad muscle which passes upwards and is inserted between the superior and inferior nuchal lines of the occipital bone. The medial part, usually more or less distinct from the remainder of the muscle, is termed the *Spinalis capitis*: it is also named the *Biventer cervicis* since it is traversed by an imperfect tendinous inscription.

The **Multifidus** consists of a number of fleshy and tendinous fasciculi, which fill the groove on the side of the spinous processes of the vertebræ, from the sacrum to the epistropheus. In the sacral region, the fasciculi arise from the back of the sacrum, as low as the fourth sacral foramen, from the aponeurosis of origin of the Sacrospinalis, from the medial surface of the posterior superior iliac spine, and from the posterior sacro-iliac ligaments; in the lumbar region, from all the mamillary processes; in the thoracic region, from all the transverse processes; and in the cervical region, from the articular processes of the lower four vertebræ. Each fasciculus passes obliquely upwards and medialwards and is inserted into the whole length of the spinous process of one of the vertebræ above. The fasciculi vary in length: the most superficial pass from one vertebra to the third or fourth above; those next in order run from one vertebra to the second or third above; while the deepest connect contiguous vertebræ.

The **Rotatores** lie beneath the Multifidus and are found only in the thoracic region; they are eleven in number on either side and are small and somewhat quadrilateral in form. Each arises from the upper and posterior part of the transverse process, and is inserted into the lower border and lateral surface of the lamina of the vertebra above, the fibres extending as far as the root of the spinous process. The first is found between the first and second thoracic vertebræ; the last, between the eleventh and twelfth. Sometimes the number of these muscles is diminished by the absence of one or more from the upper or lower end of the series.

The **Interspinales** are short muscular fasciculi, placed in pairs between the spinous processes of the contiguous vertebræ, one on either side of the interspinal ligament. In the *cervical region* they are most distinct, and consist of six pairs, the first being situated between the epistropheus and third vertebra, and the last between the seventh cervical and the first thoracic. They are small narrow bundles, attached, above and below, to the apices of the spinous processes. In the *thoracic region* they are found between the first and second vertebræ, and sometimes between the second and third, and between the eleventh and twelfth. In the *lumbar region* there are four pairs in the intervals between the five lumbar vertebræ. There is also occasionally one between the last thoracic and first lumbar, and one between the fifth lumbar and the sacrum.

The **Extensor coccygis** is a slender muscular fasciculus, which is not always present; it extends over the lower part of the posterior surface of the sacrum and coccyx. It arises by tendinous fibres from the last segment of the sacrum, or first piece of the coccyx, and passes downwards to be inserted into the lower part of the coccyx. It is a rudiment of the Levator caudæ muscle of the lower animals.

The **Intertransversarii** are small muscles placed between the transverse processes of the vertebræ. In the *cervical region* they are best developed and consist of paired muscular and tendinous fasciculi; they pass between the anterior and the posterior tubercles respectively of the transverse processes of two contiguous vertebræ, and are separated from one another by the anterior division of the cervical nerve, which lies in the groove between them. The muscles connecting the anterior tubercles are termed the *Intertransversarii anteriores*; those between the posterior tubercles the *Intertransversarii posteriores*; both sets are supplied by the anterior divisions of the spinal nerves.

(Lickley *). There are seven pairs of these muscles, the first pair being between the atlas and epistropheus, and the last between the seventh cervical and first thoracic vertebræ. In the *thoracic region* they are present between the transverse processes of the lower three thoracic, and between the transverse processes of the last thoracic and the first lumbar vertebræ. In the *lumbar region* they are arranged in pairs, on either side of the vertebral column; one set, occupying the entire interspace between the transverse processes of the lumbar vertebræ, the *Intertransversarii laterales*; the other set, *Intertransversarii mediales*, passing from the accessory process of one vertebra to the mamillary of the vertebra below. The *Intertransversarii laterales* are supplied by the anterior divisions, and the *Intertransversarii mediales* by the posterior divisions of the spinal nerves (Lickley, *loc. cit.*).

II. SUBOCCIPITAL MUSCLES (fig. 528)

Rectus capitis posterior major.
Rectus capitis posterior minor.

Obliquus capitis inferior.
Obliquus capitis superior.

The **Rectus capitis posterior major** arises by a pointed tendon from the spinous process of the epistropheus and, becoming broader as it ascends, is inserted into the lateral part of the inferior nuchal line of the occipital bone and the surface of the bone immediately below the line. As the muscles of the two sides pass upwards and lateralwards, they leave between them a triangular space, in which the *Recti capitis posteriores minores* are seen.

The **Rectus capitis posterior minor** arises by a narrow pointed tendon from the tubercle on the posterior arch of the atlas, and, widening as it ascends, is inserted into the medial part of the inferior nuchal line of the occipital bone and the surface between it and the foramen magnum.

The **Obliquus capitis inferior**, the larger of the two Oblique muscles, arises from the apex of the spinous process of the epistropheus, and passes lateralwards and slightly upwards, to be inserted into the lower and back part of the transverse process of the atlas.

The **Obliquus capitis superior**, narrow below, wide and expanded above, arises by tendinous fibres from the upper surface of the transverse process of the atlas, joining with the insertion of the *Obliquus capitis inferior*. It passes upwards and medialwards, and is inserted into the occipital bone, between the superior and inferior nuchal lines, laterally to the *Semispinalis capitis*.

The suboccipital triangle.—This triangle is bounded, above and medially, by the *Rectus capitis posterior major*; above and laterally, by the *Obliquus capitis superior*; below and laterally, by the *Obliquus capitis inferior*. It is covered by a layer of dense fibrofatty tissue, situated beneath the *Semispinalis capitis*. The floor is formed by the posterior occipito-atlantal membrane, and the posterior arch of the atlas. In the groove on the upper surface of the posterior arch of the atlas are the vertebral artery and the first cervical nerve.

Nerves.—The deep muscles of the back and the suboccipital muscles are supplied by the posterior divisions of the spinal nerves.

Actions.—The *Sacrospinalis* and its upward continuations and the *Spinales* serve to maintain the vertebral column in the erect posture; they also serve to bend the trunk backwards when it is required to counterbalance the influence of any weight at the front of the body—as, for instance, when a heavy weight is suspended from the neck, or when there is any great abdominal distension, as in pregnancy or dropsy; the peculiar gait under such circumstances depends upon the vertebral column being drawn backwards by the counterbalancing action of the *Sacrospinales*. The muscles which form the continuation of the *Sacrospinales* on the head and neck steady those parts and fix them in the upright position. If the *Iliocostalis lumborum* and *Longissimus dorsi* of one side act, they serve to draw down the chest and vertebral column to the corresponding side. The *Iliocostalis cervicis*, taking its fixed points from the cervical vertebræ, elevates those ribs to which it is attached; taking their fixed points from the ribs, the two muscles help to extend the neck; while one bends the neck to its own side. When both *Longissimi*

cervicis act from below, they bend the neck backwards. When both *Longissimi capitis* act from below, they bend the head backwards; if only one acts, the face is turned to the side on which the muscle is acting, and then the head is bent to the shoulder. The two *Recti* draw the head backwards. The *Rectus capitis posterior major*, owing to its obliquity, rotates the skull, with the atlas, round the dens of the *epistropheus*, turning the face to the same side. The *Multifidus* acts successively upon the different parts of the column: thus, the sacrum furnishes a fixed point from which the fasciculi of this muscle act upon the lumbar region; this in turn becomes the fixed point for the fasciculi moving the thoracic region, and so on throughout the entire length of the column. The *Multifidus* serves to rotate the column, so that the front of the trunk is turned to the side opposite to that from which the muscle acts. The *Obliquus capitis superior* draws the head backwards and to its own side. The *Obliquus capitis inferior* rotates the atlas, and with it the skull, round the dens of the *epistropheus*, turning the face to the same side. When the *Semispinales* of the two sides act together, they help to extend the vertebral column; when the muscles of only one side act, they rotate the thoracic and cervical parts of the column, turning the body to the opposite side. The *Semispinales capitis* draw the head directly backwards; if one muscle acts, it draws the head to one side, and rotates it so that the face is turned to the opposite side. The *Interspinales* by approximating the spinous processes help to extend the vertebral column. The *Intertransversarii* approximate the transverse processes, and help to bend the column laterally. The *Rotatores* assist in rotating the vertebral column, so that the front of the trunk is turned to the side opposite to that from which the muscles act.

Applied Anatomy.—In cases of tuberculous caries of the vertebral bodies, and in other diseases affecting the vertebral column, rigidity of the spinal muscles is one of the earliest and most constant symptoms. A child with commencing spinal disease always maintains the affected portion of the column in a state of absolute rigidity, to prevent the inflamed structures from being moved against each other; this is one of the best examples of nature's method of producing rest of an affected part.

III. MUSCLES OF THE THORAX

<i>Intercostales externi.</i>	<i>Serratus posterior inferior.</i>
<i>Intercostales interni.</i>	<i>Serratus posterior superior.</i>
<i>Subcostales.</i>	<i>Levatores costarum.</i>
<i>Transversus thoracis.</i>	<i>Diaphragm.</i>

The *Intercostales* (fig. 549) are two thin planes of muscular and tendinous fibres occupying each of the intercostal spaces. They are named *external* and *internal* from their surface relations—the external being superficial to the internal.

The *Intercostales externi* are eleven in number on either side. Their attachments extend from the tubercles of the ribs behind, to near the cartilages of the ribs in front, where each is replaced by a layer of fascia named the *anterior intercostal membrane*, which is continued forwards to the sternum. Each arises from the lower border of a rib, and is inserted into the upper border of the rib below. In the lower two spaces they extend to the ends of the cartilages, and in the upper two or three spaces they do not quite reach the ends of the ribs. They are thicker than the *Intercostales interni*, and their fibres are directed obliquely downwards and lateralwards on the back of the thorax, and downwards, forwards, and medialwards on the front.

The *Intercostales interni* are also eleven in number on either side. Their attachments commence anteriorly at the sternum, in the interspaces between the cartilages of the true ribs, and at the anterior extremities of the cartilages of the false ribs, and extend backwards as far as the angles of the ribs, where each is replaced by a layer of fascia named the *posterior intercostal membrane*, which is continued to the vertebral column. Each arises from the ridge on the inner surface of a rib, as well as from the corresponding costal cartilage, and is inserted into the upper border of the rib below. Their fibres are also

directed obliquely, but pass in a direction opposite to those of the *Intercostales externi*.

The *Subcostales* consist of muscular and aponeurotic fasciculi, and are usually well developed only in the lower part of the thorax; each arises from the inner surface of one rib near its angle, and is inserted into the inner surface of the second or third rib below. Their fibres run in the same direction as those of the *Intercostales interni*.

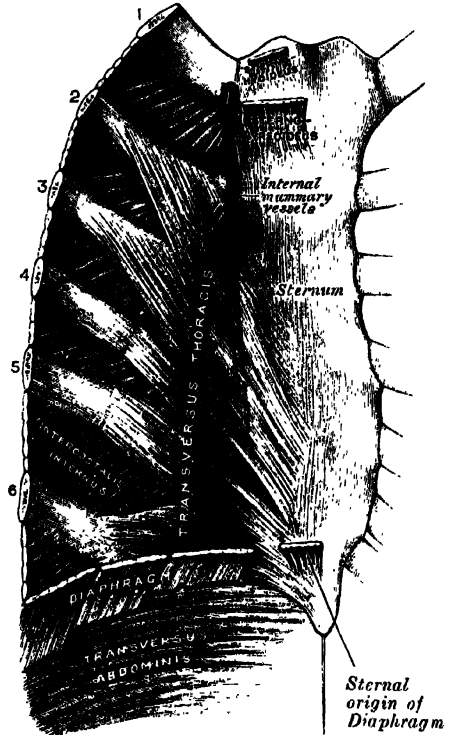
The *Transversus thoracis* (*Triangularis sterni*) is a thin plane of muscular and tendinous fibres, situated upon the inner surface of the front wall of the chest (fig. 529). It arises on either side from the lower third of the posterior surface of the body of the sternum, from the posterior surface of the xiphoid process, and from the posterior surfaces of the costal cartilages of the lower three or four true ribs near their sternal ends. Its fibres diverge upwards and lateralwards, to be inserted by slips into the lower borders and inner surfaces of the costal cartilages of the second, third, fourth, fifth, and sixth ribs. The lowest fibres of this muscle are horizontal in their direction, and are continuous with those of the *Transversus abdominis*; the intermediate fibres are oblique, while the highest are almost vertical. This muscle varies in its attachments, not only in different subjects, but on opposite sides of the same subject.

The *Levatores costarum* (fig. 528), twelve in number on either side, are small tendinous and fleshy bundles, which arise from the ends of the transverse processes of the seventh cervical and upper eleven thoracic vertebrae; they pass obliquely downwards and lateralwards, like the fibres of the *Intercostales externi*, and each is inserted into the outer surface of the rib immediately below the vertebra from which it takes origin, between the tubercle and the angle (*Levatores costarum breves*). Each of the four lower muscles divides into two fasciculi, one of which is inserted as above described; the other passes down to the second rib below its origin (*Levatores costarum longi*).

The *Serratus posterior superior* is a thin, quadrilateral muscle, situated at the upper and back part of the thorax. It arises by a thin aponeurosis from the lower part of the *ligamentum nuchæ*, from the spinous processes of the seventh cervical and upper two or three thoracic vertebrae and from the *supraspinal ligament*. Inclining downwards and lateralwards it is inserted, by four fleshy digitations, into the upper borders and outer surfaces of the second, third, fourth, and fifth ribs, a little beyond their angles.

The *Serratus posterior inferior* (fig. 547) is situated at the junction of the thoracic and lumbar regions: it is of an irregularly quadrilateral form, broader than the preceding, and separated from it by a wide interval. It arises by a thin aponeurosis from the spinous processes of the lower two thoracic and upper two or three lumbar vertebrae, and from the *supraspinal ligament*; this aponeurosis is intimately blended with the *lumbodorsal fascia*. Passing

FIG. 529.—Posterior surface of sternum and costal cartilages, showing *Transversus thoracis*.



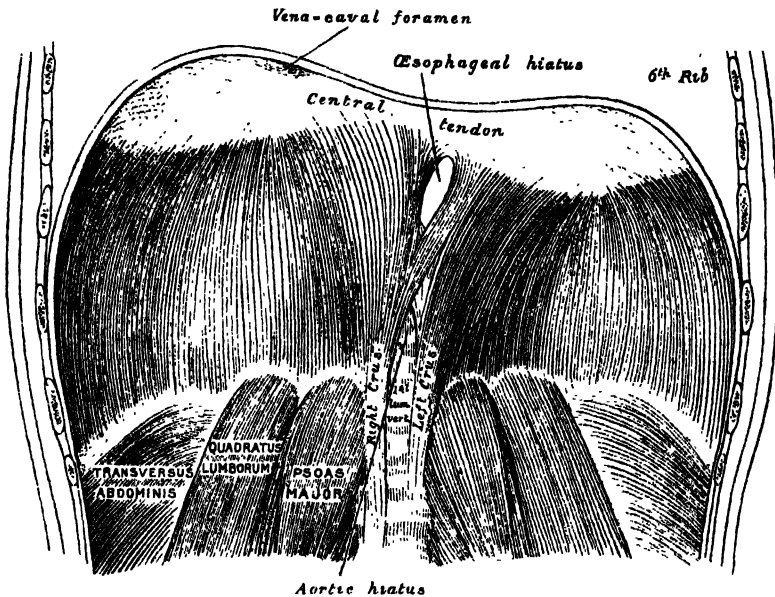
obliquely upwards and lateralwards, it becomes fleshy, and is inserted by four digitations into the inferior borders and outer surfaces of the lower four ribs, a little beyond their angles.

Nerves.—The muscles of this group are supplied by the intercostal nerves.

The **Diaphragm** (figs. 530, 531) is a dome-shaped musculofibrous septum which separates the thoracic from the abdominal cavity, its convex upper surface forming the floor of the former, and its concave under surface the roof of the latter. Its peripheral part consists of muscular fibres which take origin from the circumference of the thoracic outlet and converge to be inserted into a central tendon.

The muscular fibres may be grouped according to their origins into three parts—sternal, costal, and lumbar. The *sternal part* arises by two fleshy slips from the back of the xiphoid process; the *costal part* from the inner surfaces of the cartilages and adjacent portions of the lower six ribs on either side, interdigitating with the Transversus abdominis; and the *lumbar part*

FIG. 530.—Posterior half of Diaphragm. (Modified from model by His.)



from aponeurotic arches, named the lumbocostal arches, and from the lumbar vertebræ by two pillars or *crura*. There are two lumbocostal arches, a medial and a lateral, on either side.

The *medial lumbocostal arch* (internal arcuate ligament) is a tendinous arch in the fascia covering the upper part of the Psoas major; medially, it is continuous with the lateral tendinous margin of the corresponding crus, and is attached to the side of the body of the first or second lumbar vertebra; laterally, it is fixed to the front of the transverse process of the first lumbar vertebra.

The *lateral lumbocostal arch* (external arcuate ligament) arches across the upper part of the Quadratus lumborum, and is attached, medially, to the front of the transverse process of the first lumbar vertebra, and, laterally, to the tip and lower margin of the twelfth rib.

The crura.—At their origins the crura are tendinous in structure, and blend with the anterior longitudinal ligament of the vertebral column. The *right crus*, larger and longer than the left, arises from the anterior surfaces of the bodies and intervertebral fibrocartilages of the upper three lumbar vertebræ, while the *left crus* arises from the corresponding parts of the upper two only. The medial tendinous margins of the crura occasionally meet in the middle

line to form an arch across the front of the aorta; this arch is often poorly defined.

From this series of origins the fibres of the Diaphragm converge to be inserted into the central tendon. The fibres arising from the xiphoid process are very short, and occasionally aponeurotic; those from the medial and lateral lumbocostal arches, and more especially those from the ribs and their cartilages, are longer, and describe marked curves as they ascend and converge to their insertion. The fibres arising from the crura diverge as they ascend, the most lateral being directed upwards and lateralwards to the central tendon. The medial fibres of the right crus ascend on the left side of the œsophageal hiatus, and occasionally a fasciculus of the left crus crosses the aorta and runs obliquely through the fibres of the right crus towards the venacaval foramen (Low *).

The *central tendon* of the Diaphragm is a thin but strong aponeurosis situated near the centre of the vault formed by the muscle, but somewhat closer to the front than to the back of the thorax, so that the posterior muscular fibres are the longer. It is situated immediately below the pericardium, with which it is partially blended. It is shaped somewhat like a trefoil leaf, consisting of three divisions or leaflets separated from one another by slight indentations. The right leaflet is the largest, the middle, directed towards the xiphoid process, the next in size, and the left the smallest. In structure the tendon is composed of several planes of fibres, which intersect one another at various angles and unite into straight or curved bundles—an arrangement which gives it additional strength.

Openings in the Diaphragm.—The Diaphragm is pierced by a series of apertures to permit of the passage of structures between the thorax and abdomen. Three large openings—the aortic, the œsophageal, and the venacaval—and a number of smaller ones are present.

The *aortic hiatus* is the lowest and most posterior of the large apertures; it lies at the level of the twelfth thoracic vertebra slightly to the left of the middle line. Strictly speaking, it is not an aperture in the Diaphragm but an osseo-aponeurotic opening between it and the vertebral column, and therefore behind the Diaphragm; occasionally some tendinous fibres prolonged across the bodies of the vertebræ from the medial parts of the lower ends of the crura pass behind the aorta, and thus convert the hiatus into a fibrous ring. Through it pass the aorta, the *azygos vein*, and the thoracic duct; occasionally the *azygos vein* pierces the right crus.

The *œsophageal hiatus* is situated in the muscular part of the Diaphragm at the level of the tenth thoracic vertebra, and is elliptical in shape. It is placed above, in front, and a little to the left of the aortic hiatus, and transmits the œsophagus, the vagus nerves, and some small œsophageal vessels.

The *venacaval foramen* is the highest of the three, and is situated about the level of the fibrocartilage between the eighth and ninth thoracic vertebræ. It is quadrilateral in form, and is placed at the junction of the right and middle leaflets of the central tendon, so that its margins are tendinous. It transmits the *inferior vena cava*, the wall of which is adherent to the margin of the opening, and some branches of the *right phrenic nerve*.

Of the *lesser apertures*, two in the right crus transmit the greater and lesser right splanchnic nerves; three in the left crus give passage to the greater and lesser left splanchnic nerves and the hemiazygos vein. The gangliated trunks of the sympathetic usually enter the abdominal cavity behind the Diaphragm, under the medial lumbocostal arches. The structures piercing the crura are sometimes utilised to divide each crus into three parts—medial, intermediate, and lateral. Between the medial and intermediate crura pass the hemiazygos vein and the splanchnic nerves; between the intermediate crus and the lateral crus (which consists of the fibres rising from the medial lumbocostal arch) the gangliated trunks of the sympathetic pass.

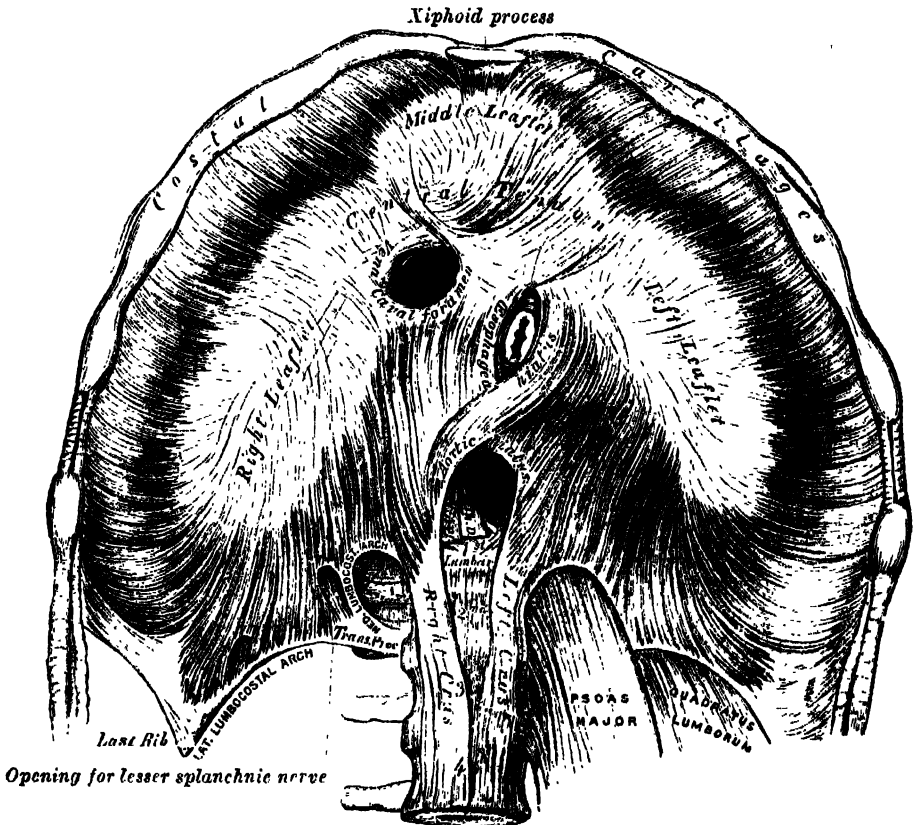
On either side two small intervals exist at which the muscular fibres of the Diaphragm are deficient and are replaced by areolar tissue. One between the sternal and costal parts transmits the superior epigastric branch of the internal mammary artery, and some lymphatics from the abdominal wall and convex surface of the liver. The other, between the fibres springing from

* *Journal of Anatomy and Physiology*, vol. xlii.

the medial and lateral lumbocostal arches, is less constant; when this interval exists, the upper and back part of the kidney is separated from the pleura by areolar tissue only.

Relations.—The upper surface of the Diaphragm is in relation with three serous membranes, viz. on either side the pleura, which separates it from the base of the corresponding lung, and on the middle leaflet of the central tendon the pericardium, which intervenes between it and the heart. The central portion lies on a slightly lower

FIG. 531.—The Diaphragm. Under surface.



level than the summits of the lateral portions. The greater part of the under surface is covered by the peritoneum. The right side is accurately moulded over the convex surface of the right lobe of the liver, the right kidney, and right suprarenal gland; the left over the left lobe of the liver, the fundus of the stomach, the spleen, the left kidney, and the left suprarenal gland.

Nerves.—The Diaphragm is supplied by the phrenic and lower six or seven intercostal nerves.

Actions.—The Diaphragm is the principal muscle of inspiration, and presents the form of a dome concave towards the abdomen. The central part of the dome is tendinous, and the pericardium is attached to its upper surface; the circumference is muscular. During inspiration the lowest ribs are fixed, and from these and the crura the muscular fibres contract and draw downwards and forwards the central tendon with the attached pericardium. In this movement the curvature of the Diaphragm is scarcely altered, the dome moving downwards nearly parallel to its original position and pushing before it the abdominal viscera. The descent of the abdominal viscera is permitted by the extensibility of the abdominal wall, but the limit of this is soon reached. The central tendon applied to the abdominal

viscera then becomes a fixed point for the action of the Diaphragm, the effect of which is to elevate the lower ribs and through them to push forwards the body of the sternum and the upper ribs. The right cupola of the Diaphragm, lying on the liver, has a greater resistance to overcome than the left, which lies over the stomach, but to compensate for this the right crus and the fibres of the right side generally are stronger than those of the left.

The height of the Diaphragm is constantly varying during respiration; it also varies with the degree of distension of the stomach and intestines and with the size of the liver. After a forced expiration the right cupola is on a level in front with the fourth costal cartilage, at the side with the fifth, sixth, and seventh ribs, and behind with the eighth rib; the left cupola is a little lower than the right. Halls Dally * states that the absolute range of movement between deep inspiration and deep expiration averages in the male and female 30 mm. on the right side and 28 mm. on the left; in quiet respiration the average movement is 12.5 mm. on the right side and 12 mm. on the left.

In all expulsive acts the Diaphragm is called into action to give additional power to each effort. Thus, before sneezing, coughing, laughing, crying, or vomiting, and previous to the expulsion of urine or faeces, or of the foetus from the uterus, a deep inspiration takes place.

Skiagraphy shows that the height of the Diaphragm in the thorax varies considerably with the position of the body. It stands highest when the body is horizontal and the patient on his back, and in this position it performs the largest respiratory excursions with normal breathing. When the body is erect the dome of the Diaphragm falls, and its respiratory movements become smaller. The dome falls still lower when the sitting posture is assumed, and in this position its respiratory excursions are smallest. These facts may, perhaps, explain why it is that patients suffering from severe dyspnoea are most comfortable and least short of breath when they sit up. When the body is horizontal and the patient on his side, the two halves of the Diaphragm do not behave alike. The uppermost half sinks to a level lower even than when the patient sits, and moves little with respiration; the lower half rises higher in the thorax than it does when the patient is supine, and its respiratory excursions are much increased. In unilateral disease of the pleura or lungs analogous interference with the position or movement of the Diaphragm can generally be observed skiagraphically.

It appears that the position of the Diaphragm in the thorax depends upon three main factors, viz.: (1) the elastic retraction of the lung-tissue, tending to pull it upwards; (2) the pressure exerted on its under surface by the viscera: this naturally tends to be a negative pressure, or downward suction, when the patient sits or stands, and a positive, or upward pressure, when he lies; (3) the intra-abdominal tension due to the abdominal muscles. These muscles are in a state of contraction in the standing position and not in the sitting; hence the Diaphragm is pushed up higher in the former position.

The referred pains felt when the Diaphragm is inflamed are described on page 895.

The Intercostales interni and externi have probably little action in moving the ribs. They contract simultaneously and form strong elastic supports which prevent the intercostal spaces being pushed out or drawn in during respiration. The anterior portions of the Intercostales interni probably have an additional function in keeping the sternocostal and interchondral joint surfaces in apposition, the posterior parts of the Intercostales externi performing a similar function for the costovertebral articulations. The Levatores costarum being inserted near the fulcra of the ribs can have little action on the ribs: they act as rotators and lateral flexors of the vertebral column. The Transversus thoracis draws down the costal cartilages, and is therefore a muscle of expiration.

The Serrati are respiratory muscles. The Serratus posterior superior elevates the ribs and is therefore an inspiratory muscle. The Serratus posterior inferior draws the lower ribs downwards and backwards, and thus elongates the thorax; it also fixes the lower ribs, thus assisting the inspiratory action of the Diaphragm and resisting the tendency of the latter to draw the lower ribs upwards and forwards. It must therefore be regarded as a muscle of inspiration.

* *Journal of Anatomy and Physiology*, 1908, vol. xliii.

MECHANISM OF RESPIRATION

The respiratory movements must be examined during (a) quiet respiration, and (b) deep respiration.

Quiet respiration.—The first and second pairs of ribs are fixed by the resistance of the cervical structures; the last pair, and through them the eleventh, by the Quadratus lumborum. The other ribs are elevated, so that the first two intercostal spaces are diminished while the others are increased in width. It has already been shown (p. 364) that elevation of the third, fourth, fifth, and sixth ribs leads to an increase in the anteroposterior and transverse diameters of the thorax: the vertical diameter is increased by the descent of the diaphragmatic dome so that the lungs are expanded in all directions except backwards and upwards. Elevation of the eighth, ninth, and tenth ribs is accompanied by a lateral and backward movement, leading to an increase in the transverse diameter of the upper part of the abdomen; the elasticity of the anterior abdominal wall allows a slight increase in the anteroposterior diameter of this part, and in this way the decrease in the vertical diameter of the abdomen is compensated and space provided for its displaced viscera. Expiration is effected by the elastic recoil of its walls and by the action of the abdominal muscles, which push back the viscera displaced downwards by the Diaphragm.

Deep respiration.—All the movements of quiet respiration are here carried out, but to a greater extent. In deep inspiration the shoulders and the vertebral borders of the scapulæ are fixed and the limb muscles, the Trapezius, Serratus anterior, Pectorales, and Latissimus dorsi, called into play. The Scaleni are in strong action, and the Sternocleidomastoidei also assist, when the head is fixed, by drawing up the sternum and by fixing the clavicles. The first rib is therefore no longer stationary, but, with the sternum, is raised; with it all the other ribs except the last are raised to a higher level. In conjunction with the increased descent of the Diaphragm this provides for a considerable augmentation of all the thoracic diameters. The anterior abdominal muscles come into action so that the umbilicus is drawn upwards and backwards, but this allows the Diaphragm to exert a more powerful influence on the lower ribs; the transverse diameter of the upper part of the abdomen is greatly increased and the subcostal angle opened out. The deeper muscles of the back, e.g. the Serrati posteriores superiores and the Sacrospinales and their continuations, are also brought into action; the thoracic curve of the vertebral column is partially straightened, and the whole column, above the lower lumbar vertebræ, drawn backwards. This increases the anteroposterior diameters of the thorax and upper part of the abdomen and widens the intercostal spaces. Deep expiration is effected by the recoil of the walls and by the contraction of the anterolateral muscles of the abdominal wall, and the Transversus thoracis.

Halls Dally (*loc cit.*) gives the following figures as representing the average changes which occur during deepest possible respiration. The manubrium sterni moves 30 mm. in an upward and 14 mm. in a forward direction; the width of the subcostal angle, at a level of 30 mm. below the articulation between the body of the sternum and the xiphoid process, is increased by 26 mm.; the umbilicus is retracted and drawn upwards for a distance of 13 mm.

IV. MUSCLES OF THE ABDOMEN

The muscles of the abdomen may be divided into two groups: 1. The anterolateral muscles; 2. The posterior muscles.

1. ANTEROLATERAL MUSCLES

Obliquus externus.
Obliquus internus.

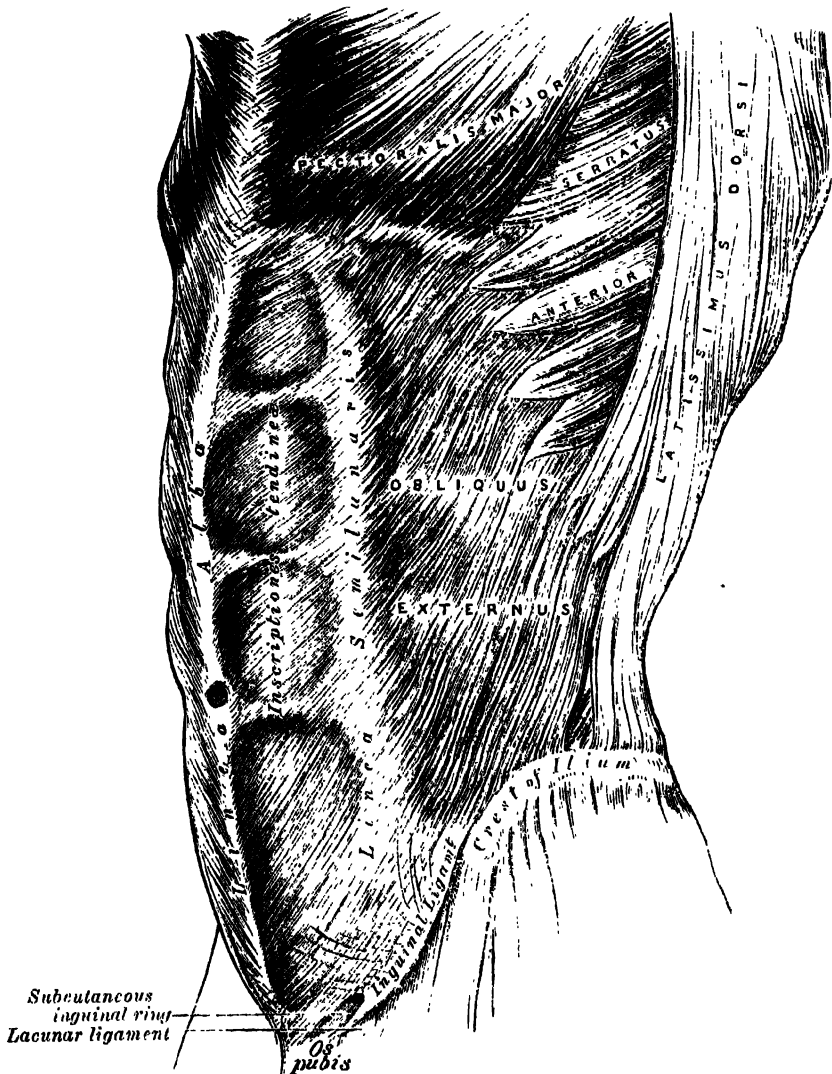
Transversus.
Rectus.

Pyramidalis.

The superficial fascia of the abdomen consists, over the greater part of the abdominal wall, of a single layer containing a variable amount of fat; but near the groin it is easily divisible into two layers, between which are found the superficial vessels and nerves and the superficial inguinal lymph-glands.

The superficial layer (*fascia of Camper*) is thick, areolar in texture, and contains in its meshes a varying quantity of adipose tissue. Below, it passes over the inguinal ligament, and is continuous with the superficial fascia of the thigh. In the male, Camper's fascia is continued over the penis and outer surface of the spermatic cord to the scrotum, where it helps to form the dartos. As it passes to the scrotum it changes its characteristics, becoming thin, destitute

FIG. 532.—The Obliquus externus abdominis.



of adipose tissue, and of a pale reddish colour; in the scrotum it acquires some involuntary muscular fibres and forms the *dartos tunic*. From the scrotum it may be traced backwards into continuity with the superficial fascia of the perinæum. In the female, Camper's fascia is continued from the abdomen into the labia majora.

The deep layer (*fascia of Scarpa*) is thinner and more membranous in character than the superficial, and contains a considerable quantity of yellow elastic fibres. It is loosely connected by areolar tissue to the aponeurosis of the Obliquus externus abdominis, but in the middle line it is more intimately adherent to the linea alba and to the symphysis pubis, and is prolonged on

to the dorsum of the penis, forming the *fundiform ligament*; above, it is continuous with the superficial fascia over the rest of the trunk; below and laterally, it blends with the fascia lata of the thigh a little below the inguinal ligament; medially and below, it is continued over the penis and spermatic cord to the scrotum, where it helps to form the dartos. From the scrotum it may be traced backwards into continuity with the deep layer of the superficial fascia of the perinæum (*fascia of Colles*). In the female, it is continued into the labia majora and thence to the fascia of Colles.

The *Obliquus externus abdominis* (fig. 532), situated on the lateral and anterior parts of the abdomen, is the largest and the most superficial of the three flat muscles in this region. It arises, by eight fleshy slips, from the external surfaces and inferior borders of the lower eight ribs; these slips interdigitate with the slips of origin of the *Serratus anterior* and *Latissimus dorsi*, and are arranged in an oblique line which runs downwards and backwards, the upper ones being attached close to the cartilages of the corresponding ribs, the lowest to the apex of the cartilage of the last rib, the intermediate ones to the ribs at some distance from their cartilages. From these attachments the fleshy fibres proceed in various directions. Those from the lowest ribs pass nearly vertically downwards, and are inserted into the anterior half of the outer lip of the iliac crest; the middle and upper fibres, directed downwards and forwards, end in an aponeurosis, opposite a line drawn from the prominence of the ninth costal cartilage to the anterior superior iliac spine.

The *aponeurosis* of the *Obliquus externus abdominis* is a thin but strong membranous structure, the fibres of which are directed downwards and medialwards. It is joined with that of the opposite muscle along the middle line, and the aponeuroses of the two muscles cover the front of the abdomen; above, it is covered by, and gives origin to, the lower fibres of the *Pectoralis major*; below, its fibres are closely aggregated together, and extend obliquely across from the anterior superior iliac spine to the pubic tubercle and the pectineal line. In the middle line, its fibres end in the *linea alba*, a tendinous band which extends from the xiphoid process to the symphysis pubis.

The free margin of that portion of the aponeurosis which extends between the anterior superior iliac spine and the pubic tubercle is a thick band, folded inwards, and continuous below with the fascia lata; it is called the *inguinal ligament*. The portion which is reflected from the inguinal ligament at the pubic tubercle is attached to the pecten pubis, and is called the *lacunar ligament*. From the attachment of the latter to the pecten pubis, a few fibres pass upwards and medialwards, behind the medial crus of the subcutaneous inguinal ring, to the linea alba; they diverge as they ascend, and form a thin triangular fibrous band which is called the *reflected inguinal ligament*.

In the aponeurosis of the *Obliquus externus*, immediately above the crest of the os pubis, is a triangular opening, the *subcutaneous inguinal ring*, formed by a separation of the fibres of the aponeurosis in this situation.

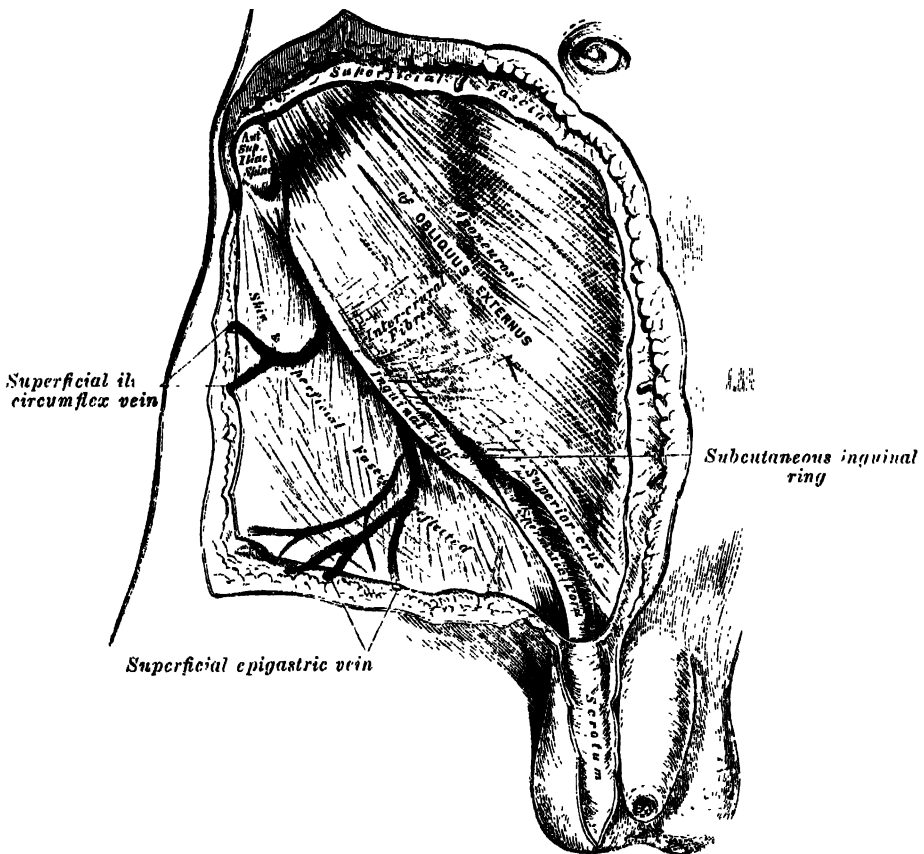
The following structures require further description, viz. the subcutaneous inguinal ring, the intercrural fibres and fascia, and the inguinal, lacunar, and reflected inguinal ligaments.

The *subcutaneous inguinal ring* (external abdominal ring) (figs. 532, 533) is an interval in the aponeurosis of the *Obliquus externus*, just above and lateral to the crest of the os pubis. The aperture is somewhat triangular in form, and its direction is oblique, corresponding with the course of the fibres of the aponeurosis. It measures from base to apex about 2.5 cm., and across the base about 1.25 cm. It is bounded below by the crest of the os pubis; on either side by the margins of the opening in the aponeurosis, which are called the *crura of the ring*; and above, by a series of curved *intercrural fibres*. The inferior crus (external pillar) is the stronger and is formed by that portion of the inguinal ligament which is inserted into the pubic tubercle; it is so curved as to form a kind of groove, upon which, in the male, the spermatic cord rests. The superior crus (internal pillar) is a thin, flat band, attached to the front of the symphysis pubis and interlacing with its fellow of the opposite side.

The subcutaneous inguinal ring gives passage to the spermatic cord and ilio-inguinal nerve in the male, and to the round ligament of the uterus and the ilio-inguinal nerve in the female; it is much larger in men than in women, on account of the size of the spermatic cord.

The **intercrural fibres** (intercolumnar fibres) are a series of curved tendinous fibres, which arch across the lower part of the aponeurosis of the *Obliquus externus*, describing curves with the convexities downwards. They have received their name from stretching across between the two crura of the subcutaneous inguinal ring, and they are much thicker and stronger at the inferior crus, where they are connected to the inguinal ligament, than superiorly, where they are inserted into the linea alba. The intercrural fibres increase the strength of the lower part of the aponeurosis, and tend to prevent the divergence of the crura from one another; they are more strongly developed in the male than in the female.

FIG. 533.—The subcutaneous inguinal ring



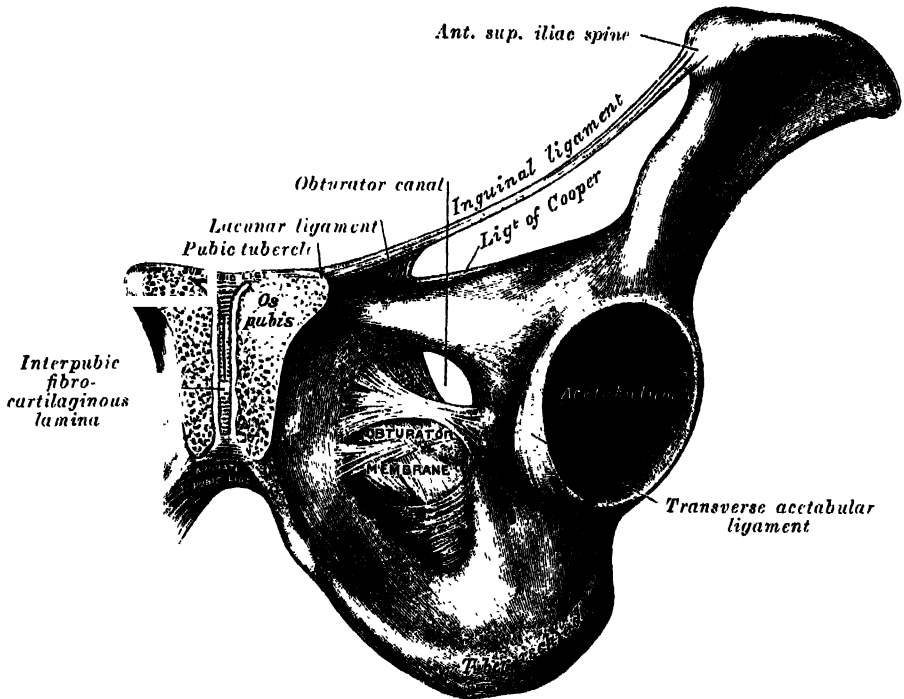
As they pass across the subcutaneous inguinal ring, they are connected together by delicate fibrous tissue, forming a fascia, called the *intercrural fascia*. This intercrural fascia is continued down as a tubular prolongation around the spermatic cord and testis, and encloses them in a sheath; hence it is also called the *external spermatic fascia*. The subcutaneous inguinal ring is seen as a distinct aperture only after the intercrural fascia has been removed.

The **inguinal ligament** (Poupart's ligament) (figs. 533, 534) is the lower border of the aponeurosis of the *Obliquus externus*, and extends from the anterior superior iliac spine to the pubic tubercle. From this latter point it is reflected backwards and lateralwards as the lacunar ligament which is attached to the pecten pubis for about 1.25 cm. Its general direction is convex downwards towards the thigh, where it is continuous with the fascia lata. Its lateral half is rounded, and oblique in direction; its medial half gradually

widens at its attachment to the os pubis, is more horizontal in direction, and supports the spermatic cord.

The **lacunar ligament** (Gimbernat's ligament) (figs. 534) is that part of the aponeurosis of the *Obliquus externus* which is reflected backwards and lateralwards, to be attached to the pecten pubis. It is of a triangular form, and is almost horizontal in direction when the body is in the erect posture; it is a little larger in the male than in the female, and measures about 2 cm. from base to apex. Its base, directed laterally, is concave, thin, and sharp, and forms the medial boundary of the femoral ring; its apex corresponds to the pubic tubercle. Its posterior margin is attached to the pecten pubis, and is continuous with the pectineal fascia; its anterior margin is attached to the inguinal ligament. Its surfaces are directed upwards and downwards.

FIG. 534.—The inguinal and lacunar ligaments.



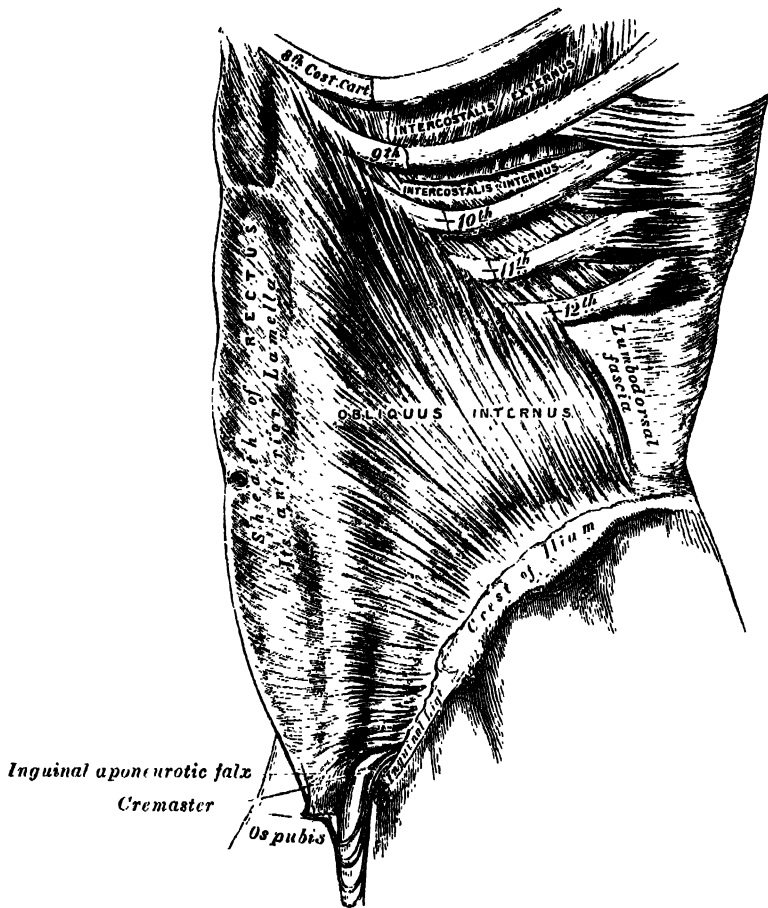
The **reflected inguinal ligament** (triangular fascia) is a triangular-shaped layer of tendinous fibres; it is formed by an expansion from the lacunar ligament and the inferior crus of the subcutaneous inguinal ring. It passes medialwards behind the spermatic cord, expands into a somewhat fan-shaped band behind the superior crus of the subcutaneous inguinal ring and in front of the inguinal aponeurotic falx, and interlaces with the ligament of the other side at the linea alba.

Ligament of Cooper.—This is a strong fibrous band, which was first described by Sir Astley Cooper. It extends lateralwards from the base of the lacunar ligament (fig. 534) along the pecten pubis, to which it is attached. It is strengthened by the pectineal fascia, and by a lateral expansion from the lower attachment of the linea alba (*adminiculum lineæ albæ*).

The ***Obliquus internus abdominis*** (fig. 535), thinner and smaller than the *Obliquus externus*, beneath which it lies, is of an irregularly quadrilateral form. It arises, by fleshy fibres, from the lateral half of the grooved upper surface of the inguinal ligament, from the anterior two-thirds of the middle lip of the iliac crest, and from the posterior lamella of the lumbodorsal fascia. From this origin the fibres diverge; those from the inguinal ligament, few in number, and paler in colour than the rest, arch downwards and medialwards

across the spermatic cord in the male, and the round ligament of the uterus in the female, and, becoming tendinous, are inserted, conjointly with those of the Transversus, into the crest of the os pubis and into the medial part of the pecten pubis behind the lacunar ligament, forming what is known as the inguinal aponeurotic falx. Those from the anterior third of the iliac origin are horizontal in their direction, and, becoming tendinous along the lower fourth of the linea semilunaris, pass in front of the Rectus abdominis to be inserted into the linea alba. Those arising from the middle third of the iliac origin run obliquely

FIG. 535.—The Obliquus internus abdominis.

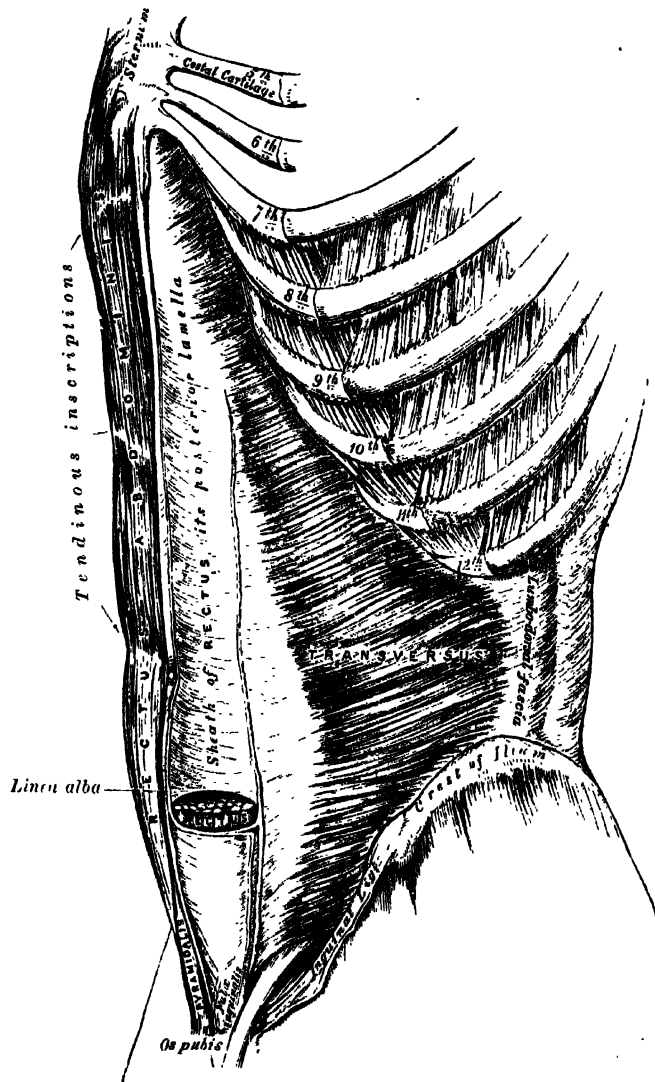


upwards and medialwards, and end in an aponeurosis; this divides at the lateral border of the Rectus into two lamellæ, which are continued forwards, one in front of and the other behind this muscle, to the linea alba; the posterior lamella has an attachment to the cartilages of the seventh, eighth, and ninth ribs. The most posterior fibres pass almost vertically upwards, to be inserted into the inferior borders of the cartilages of the three lower ribs, being continuous with the Intercostales interni.

The **Cremaster** (fig. 535) is a thin muscular layer, composed of a number of fasciculi which arise from the middle of the inguinal ligament where its fibres are continuous with those of the Obliquus internus and also occasionally with the Transversus. It passes along the lateral side of the spermatic cord, descends with it through the subcutaneous inguinal ring upon the front and sides of the cord, and forms a series of loops which differ in thickness and length in different subjects. At the upper part of the cord the loops are short, but they become successively longer, the longest reaching down as low as the

testis, where a few are inserted into the tunica vaginalis. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, the *cremasteric fascia*. The fibres ascend along the medial side of the cord, and are inserted by a small pointed tendon into the tubercle and crest of the os pubis and into the front of the sheath of the Rectus abdominis.

FIG. 536.—The Transversus abdominis, Rectus abdominis, and Pyramidalis.

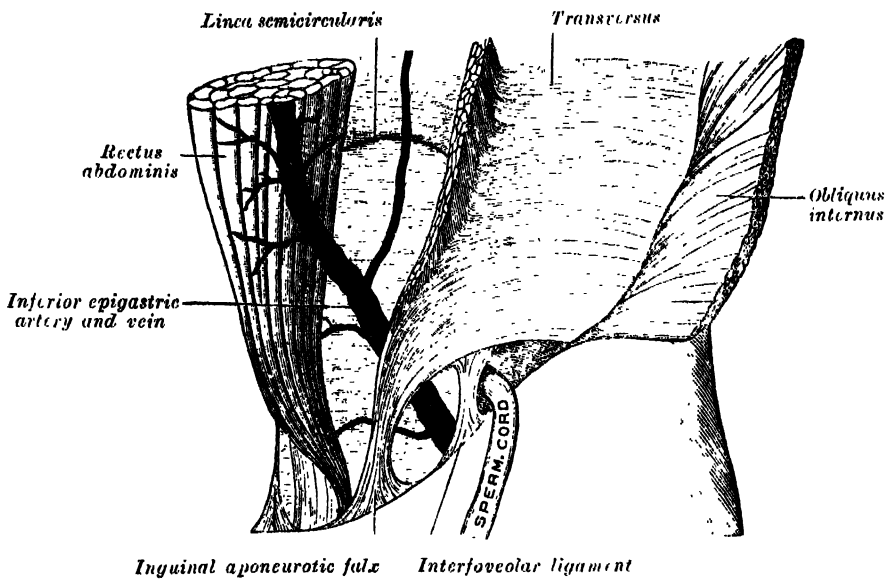


The Transversus abdominis (fig. 536), so called from the direction of its fibres, is the most internal of the flat muscles of the abdomen, being situated deep to the Obliquus internus. It arises by fleshy fibres from the lateral third of the inguinal ligament, from the anterior three-fourths of the inner lip of the iliac crest, from the inner surfaces of the cartilages of the lower six ribs, interdigitating with the Diaphragm, and from the lumbodorsal fascia. The muscle ends in front in a broad aponeurosis, the lower fibres of which curve downwards and medialwards, and are inserted, together with those of the Obliquus internus, into the crest of the os pubis and pecten pubis, forming

the inguinal aponeurotic falx. Throughout the rest of its extent the aponeurosis passes horizontally to the middle line, and is inserted into the linea alba; its upper three-fourths lie behind the Rectus and blend with the posterior lamella of the aponeurosis of the Obliquus internus; its lower fourth is in front of the Rectus.

The *inguinal aponeurotic falx*, or *conjoined tendon* of the Obliquus internus and Transversus, is mainly formed by the lower part of the tendon of the Transversus, and is inserted into the crest of the os pubis and pecten pubis, immediately behind the subcutaneous inguinal ring, serving to protect what would otherwise be a weak point in the abdominal wall. Lateral to the falx is a ligamentous band connected with the lower margin of the Transversus and extending down to the superior ramus of the os pubis; it is termed the *interfoveolar ligament* (of Hesselbach) (fig. 537), and sometimes contains a few muscular fibres.

FIG. 537.—The interfoveolar ligament, seen from in front. (Modified from Braune.)



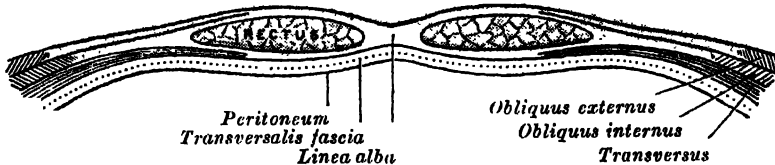
The **Rectus abdominis** (fig. 536) is a long flat muscle, broader above than below, which extends along the whole length of the front of the abdomen, and is separated from its fellow of the opposite side by the linea alba. It arises by two tendons; the lateral and larger is attached to the crest of the os pubis, the medial interlaces with its fellow of the opposite side and is connected with the ligamentous fibres covering the front of the symphysis pubis. The muscle is inserted by three slips of unequal size into the cartilages of the fifth, sixth, and seventh ribs; some fibres of the upper slip are usually inserted into the anterior extremity of the fifth rib; some are occasionally connected with the costoxiphoid ligaments and the side of the xiphoid process.

The Rectus is crossed by three fibrous bands, which are named the *tendinous inscriptions*; one is usually situated opposite the umbilicus, the second opposite the free end of the xiphoid process, and the third about midway between the xiphoid process and the umbilicus. These inscriptions pass transversely or obliquely across the muscle in a zigzag course; they rarely extend completely through its substance and may pass only halfway across it; they are intimately adherent in front to the sheath of the muscle. Sometimes one or two additional but incomplete inscriptions are present below the umbilicus.

The Rectus is enclosed in a sheath (fig. 536) formed by the aponeuroses of the Obliqui and Transversus, which are arranged in the following manner. At the lateral margin of the Rectus, the aponeurosis of the Obliquus internus

divides into two lamellæ, one of which passes in front of the Rectus, blending with the aponeurosis of the Obliquus externus, the other, behind it, blending with the aponeurosis of the Transversus, and these, joining again at the medial border of the Rectus, are inserted into the linea alba. This arrangement of the aponeuroses exists from the costal margin to midway between the umbilicus and symphysis pubis, where the posterior wall of the sheath ends in a thin

FIG. 538.—Diagram of sheath of Rectus.

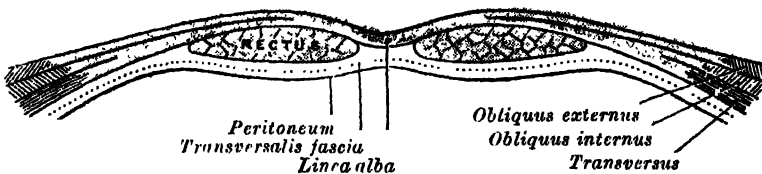


curved margin, the *linea semicircularis*, the concavity of which is directed downwards. In the upper part of the sheath muscular fibres of the Transversus extend into its posterior wall, and not infrequently do so to a considerable extent (fig. 538). Below the level of the *linea semicircularis* the aponeuroses of all three muscles pass in front of the Rectus; those of the Transversus and Obliquus internus are intimately fused together, but the aponeurosis of the Obliquus externus is bound to them merely by loose connective tissue except in and near the middle line; behind, the Rectus is separated from the peritoneum by the transversalis fascia (fig. 539). Since the tendons of the Obliquus internus and Transversus only reach as high as the costal margin, it follows that above this level the sheath of the Rectus is deficient posteriorly, the muscle resting directly on the cartilages of the ribs; in front, this part is covered merely by the tendon of the Obliquus externus.

The **Pyramidalis** (fig. 536) is a small triangular muscle, placed at the lower part of the abdomen, in front of the Rectus, and contained in the sheath of that muscle. It arises by tendinous fibres from the front of the os pubis and from the ligamentous fibres in front of the symphysis; the fleshy portion of the muscle passes upwards, diminishing in size as it ascends, and ends in a pointed extremity which is inserted into the linea alba midway between the umbilicus and os pubis, but may extend to a higher level. This muscle may be larger on one side than on the other, or may be wanting on one or both sides.

Besides the Rectus and Pyramidalis, the sheath of the Rectus contains the superior and inferior epigastric arteries, and the terminal portions of the lower intercostal nerves.

FIG. 539.—Diagram of a transverse section through the anterior abdominal wall, below the *linea semicircularis*.



The **linea alba** is a tendinous raphe in the middle line of the abdomen, stretching between the xiphoid process and the symphysis pubis. It is placed between the medial borders of the Recti, and is formed by the blending of the aponeuroses of the Obliqui and Transversi. It is narrow below, corresponding to the linear interval existing between the Recti; but broader above, where these muscles diverge from one another. Its lower end has a double attachment—its superficial fibres passing in front of the medial heads of the Recti to the symphysis pubis, while its deeper fibres form a triangular lamella, attached

behind the Recti to the posterior lip of the crest of the os pubis, and named the *adminiculum lineæ albe*. The linea alba presents apertures for the passage of vessels and nerves at the umbilicus, which in the foetus exists as an aperture and transmits the umbilical vessels, is closed a few days after birth.

The *lineæ semilunares* are two curved tendinous lines corresponding with the lateral borders of the Recti; each extends from the cartilage of the ninth rib to the pubic tubercle, and is formed by the aponeurosis of the Obliquus internus at its line of division to enclose the Rectus, reinforced in front by that of the Obliquus externus, and behind by that of the Transversus.

Nerves.—The abdominal muscles are supplied by the lower intercostal nerves. The Obliquus internus and Transversus also receive filaments from the anterior branch of the iliohypogastric and sometimes from the ilio-inguinal. The Cremaster is supplied by the external spermatic branch of the genitofemoral nerve, and the Pyramidalis usually by the twelfth thoracic.

Actions.—When the pelvis and thorax are fixed, the abdominal muscles compress the abdominal viscera, in which action they are materially assisted by the descent of the Diaphragm. By these means assistance is given in expelling the feces from the rectum, the urine from the bladder, the foetus from the uterus, and the contents of the stomach in vomiting.

If the pelvis and vertebral column be fixed, these muscles compress the lower part of the thorax, materially assisting expiration. If the pelvis alone be fixed, the thorax is bent directly forward when the muscles of both sides act; when the muscles of only one side contract, the trunk is bent towards that side and rotated towards the opposite side.

If the thorax be fixed, the muscles, acting together, draw the pelvis upwards, as in climbing; or, acting singly, they draw the pelvis upwards, and bend the vertebral column to one side or the other. The Recti, acting from below, depress the thorax, and consequently flex the vertebral column; when acting from above, they flex the pelvis upon the vertebral column. The Pyramidales are tensors of the linea alba.

The *transversalis fascia* is a thin aponeurotic membrane which lies between the inner surface of the Transversus muscle and the extraperitoneal fat. It forms part of the general layer of fascia lining the abdominal parietes, and is continuous with the iliac and pelvic fasciæ. In the inguinal region it is thick and dense in structure and is joined by fibres from the aponeurosis of the Transversus, but it becomes thin as it ascends to the Diaphragm, and blends with the fascia covering the under surface of this muscle. Behind, it is lost in the fat which covers the posterior surfaces of the kidneys. Below, it has the following attachments: posteriorly, to the whole length of the iliac crest, between the origins of the Transversus and Iliacus; between the anterior superior iliac spine and the femoral vessels it is connected to the posterior margin of the inguinal ligament, and is there continuous with the iliac fascia. Medially to the femoral vessels it is thin and is fixed to the pecten pubis, behind the inguinal aponeurotic falx, with which it is united; it descends in front of the femoral vessels to form the anterior wall of the femoral sheath. The spermatic cord in the male, and the round ligament of the uterus in the female, pass through the transversalis fascia at a spot called the *abdominal inguinal ring*. This opening is not visible externally since the transversalis fascia is prolonged on these structures as the infundibuliform fascia.

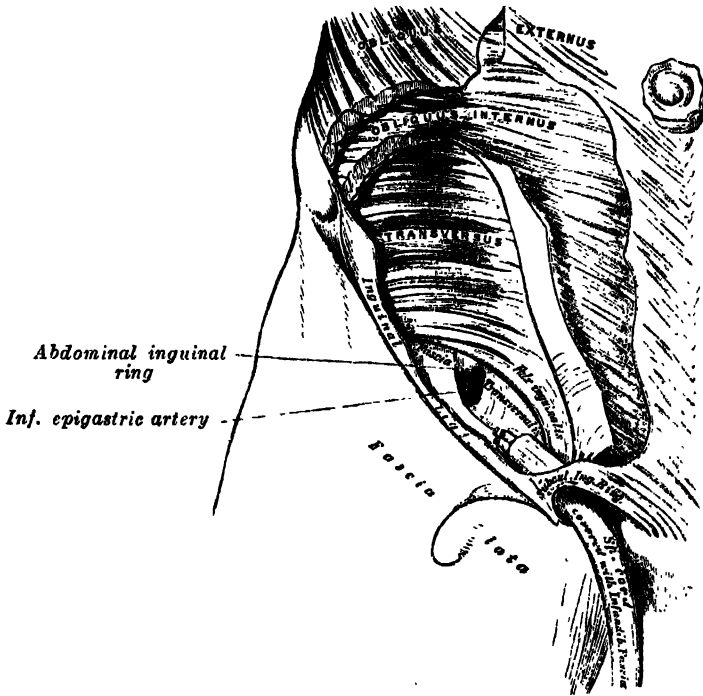
The *abdominal inguinal ring* (internal abdominal ring) is situated in the transversalis fascia, midway between the anterior superior iliac spine and the symphysis pubis, and about 1.25 cm. above the inguinal ligament (fig. 540). It is of an oval form, the long axis of the oval being vertical; it varies in size in different subjects, and is much larger in the male than in the female. It is bounded above by the arched lower margin of the Transversus, and medially by the inferior epigastric vessels. It transmits the spermatic cord in the male and the round ligament of the uterus in the female. From its circumference a thin funnel-shaped membrane, the *infundibuliform fascia*, is continued as a covering on the spermatic cord and testis.

The *inguinal canal* contains the spermatic cord and the ilio-inguinal nerve in the male, and the round ligament of the uterus and the ilio-inguinal nerve in the female. It is an oblique canal about 4 cm. long, slanting downwards and medialwards, and placed parallel with and a little above the inguinal ligament;

it extends from the abdominal inguinal ring to the subcutaneous inguinal ring. It is bounded *in front* by the integument, superficial fascia, and aponeurosis of the Obliquus externus throughout its whole length, and by the Obliquus internus in its lateral third; *behind* by the reflected inguinal ligament, the inguinal aponeurotic falx, the transversalis fascia, the extraperitoneal connective tissue, and the peritoneum; *above* by the arched fibres of the Obliquus internus and Transversus abdominis; *below* by the union of the transversalis fascia with the inguinal ligament, and at its medial end by the lacunar ligament.

Extraperitoneal connective tissue.—Between the inner surface of the general layer of the fascia which lines the interior of the abdominal and pelvic cavities, and the peritoneum, there is a considerable amount of connective tissue, termed the *extraperitoneal* or *subperitoneal connective tissue*.

FIG. 540.—The abdominal inguinal ring.



The *parietal* portion lines the cavity, and varies in quantity in different situations. It is especially abundant on the posterior wall of the abdomen, and particularly around the kidneys, where it contains much fat. It is scanty on the anterolateral wall of the abdomen, except in the pubic region and above the iliac crest; there is a considerable amount in the pelvis.

The *visceral* portion follows the course of the branches of the abdominal aorta between the layers of the mesenteries and other folds of peritoneum which connect the various viscera to the abdominal wall. The two portions are directly continuous with each other.

2. POSTERIOR MUSCLES OF THE ABDOMEN

Psoas major.
Psoas minor.

Iliacus.
Quadratus lumborum.

The Psoas major, the Psoas minor, and the Iliacus, with the fasciae covering them are described with the muscles of the lower extremity (see p. 513).

The fascia covering the Quadratus lumborum is a thin layer attached, medially, to the bases of the transverse processes of the lumbar vertebrae;

below, to the iliolumbar ligament; above, to the apex and lower border of the last rib. The upper margin of this fascia, which extends from the transverse process of the first lumbar vertebra to the apex and lower border of the last rib, constitutes the lateral lumbocostal arch (p. 452). Laterally, the fascia blends with the anterior layer of the lumbodorsal fascia, which intervenes between the *Quadratus lumborum* and the *Sacrospinalis*.

The *Quadratus lumborum* (fig. 528, p. 446) is irregularly quadrilateral in shape, and broader below than above. It arises by aponeurotic fibres from the iliolumbar ligament and the adjacent portion of the iliac crest for about 5 cm., and is inserted into the lower border of the last rib for about half its length, and by four small tendons into the apices of the transverse processes of the upper four lumbar vertebrae. Occasionally a second portion of this muscle is found in front of the preceding; it arises from the upper borders of the transverse processes of the lower three or four lumbar vertebrae, and is inserted into the lower margin of the last rib.

In front of the *Quadratus lumborum* are the colon, the kidney, the *Psoas major* and *minor*, and the *Diaphragm*; between the fascia and the muscle are the twelfth thoracic, iliohypogastric, and ilio-inguinal nerves.

Nerve-supply.—The twelfth thoracic and first and second lumbar nerves supply this muscle.

Actions.—The *Quadratus lumborum* draws down the last rib, and acts as a muscle of inspiration by helping to fix the origin of the *Diaphragm*. If the thorax and vertebral column are fixed, it may act upon the pelvis, raising it towards its own side when only one muscle is put in action; and when both muscles act together, either from below or above, they flex the trunk.

V. MUSCLES OF THE PELVIS

Obturator internus.
Piriformis.

Levator ani.
Coccygeus.

The muscles within the pelvis may be divided into two groups: (1) the *Piriformis* and the *Obturator internus*, which are described with the muscles of the lower extremity (pp. 523, 524); (2) the *Levator ani* and the *Coccygeus*, which together form the *pelvic diaphragm* and are associated with the pelvic viscera. The classification of the two groups under a common heading is convenient in connexion with the fasciæ investing the muscles. These fasciæ are closely related to one another and to the deep fascia of the perinæum, and in addition have special connexions with the fibrous coverings of the pelvic viscera; it is customary therefore to describe them together under the term *pelvic fascia*.

Pelvic fascia.—The fascia of the pelvis may be resolved into: (A) the fascial sheaths of the *Obturator internus*, *Piriformis*, and *pelvic diaphragm*; (B) the fascia associated with the pelvic viscera.

The *fascia of the Obturator internus* covers the pelvic surface of, and is attached round the margin of the origin of, the muscle. Above, it is loosely connected to the back part of the arcuate line, and here it is continuous with the iliac fascia. In front of this, as it follows the line of origin of the *Obturator internus*, it gradually separates from the iliac fascia and the continuity between the two is retained only through the periosteum. It arches beneath the obturator vessels and nerve, completing the obturator canal, and at the front of the pelvis is attached to the back of the superior ramus of the os pubis. Below, the obturator fascia is attached to the falciform process of the sacrotuberous ligament and to the pubic arch, where it becomes continuous with the superior fascia of the urogenital diaphragm. Behind, it is prolonged into the gluteal region.

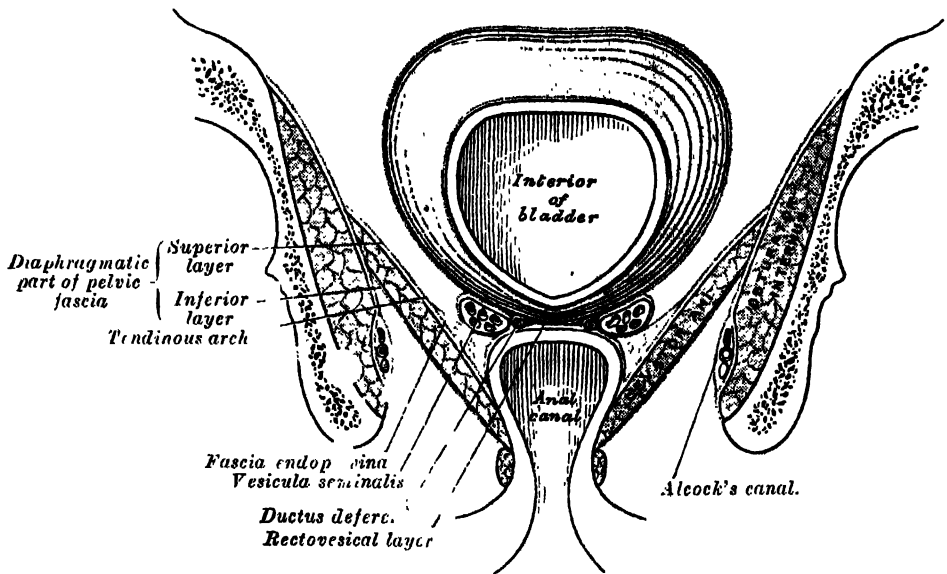
The internal pudendal vessels and pudendal nerve cross the lower part of the pelvic surface of the *Obturator internus*, and are enclosed in a special canal—*Alcock's canal*—formed by the obturator fascia.

The *fascia of the Piriformis* is very thin and is attached to the front of the sacrum and the sides of the greater sciatic foramen; it is prolonged on the

muscle into the glutæal region. At its sacral attachment round the margins of the anterior sacral foramina it comes into intimate association with and ensheathes the nerves emerging from these foramina; hence the sacral nerves are frequently described as lying behind the fascia. The internal iliac vessels and their branches, on the other hand, lie in the subperitoneal tissue in front of the fascia, and the branches of these vessels to the glutæal region emerge in special sheaths of this tissue, above and below the Piriformis muscle.

The *diaphragmatic part of the pelvic fascia* (fig. 541) covers both surfaces of the Levatores ani. That on the inferior surface of the muscle is known as the *anal fascia*; it is attached above to the obturator fascia along the line of origin of the Levator ani, while below, it is continuous with the superior fascia of the urogenital diaphragm, and with the fascia on the Sphincter ani internus. The layer covering the upper surface of the Levator ani follows, above, the line of origin of the muscle, and is therefore somewhat variable.

FIG. 541.—Coronal section of pelvis, showing arrangement of fascia.
Viewed from behind. (Diagrammatic.)



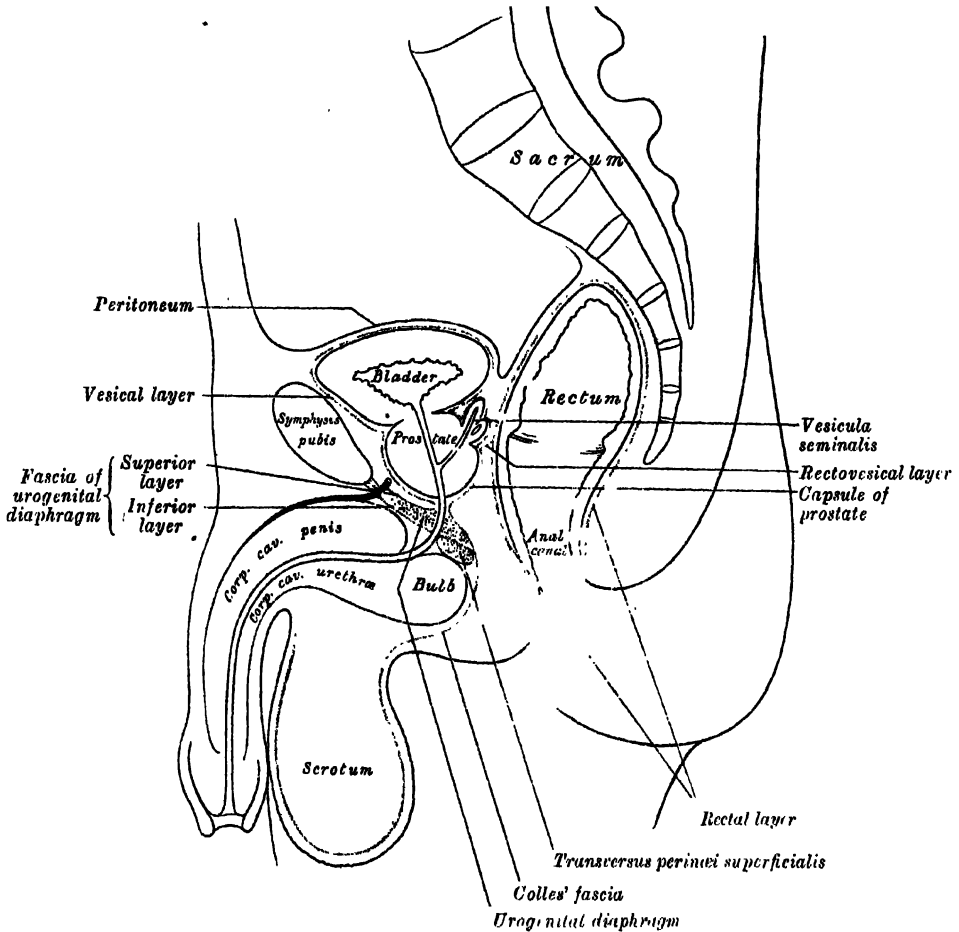
In front it is attached to the back of the symphysis pubis about 2 cm. above its lower border, and can be traced lateralwards across the back of the superior ramus of the os pubis for a distance of about 1.25 cm., when it reaches the obturator fascia. It is attached to this fascia along a line which pursues a somewhat irregular course to the spine of the ischium. The irregularity of this line is due to the fact that the origin of the Levator ani, which in lower forms is from the pelvic brim, is in man lower down, on the obturator fascia. Tendinous fibres of origin of the muscle are therefore often found extending up towards, and in some cases reaching, the pelvic brim, and on these the fascia is carried. The lower margin of the fascia covering the upper surface of the pelvic diaphragm is attached along the line of insertion of the Levator ani.

It will be evident that the fascia covering that part of the Obturator internus which lies above the origin of the Levator ani is a composite fascia and includes the following: (a) the obturator fascia; (b) the fascia of the Levator ani; (c) degenerated fibres of origin of the Levator ani.

At the level of a line extending from the lower part of the symphysis pubis to the spine of the ischium is a thickened whitish band in this upper layer of the diaphragmatic part of the pelvic fascia. It is termed the *tendinous arch* or *white line* of the pelvic fascia, and marks the line of attachment of the special fascia (*pars endopelvina fasciæ pelyis*) which is associated with the pelvic viscera.

The *endopelvic part of the pelvic fascia* is continued over the various pelvic viscera (fig. 542), to form for them fibrous coverings which will be described later (see section on Splanchnology). It is attached to the diaphragmatic part of the pelvic fascia along the tendinous arch, and has been subdivided in accordance with the viscera to which it is related. Thus its anterior part, known as the *vesical layer*, forms the anterior and lateral ligaments of the bladder. Its middle part crosses the floor of the pelvis between the rectum

FIG. 542.—Median sagittal section of pelvis, showing arrangement of fascia.
(Diagrammatic.)

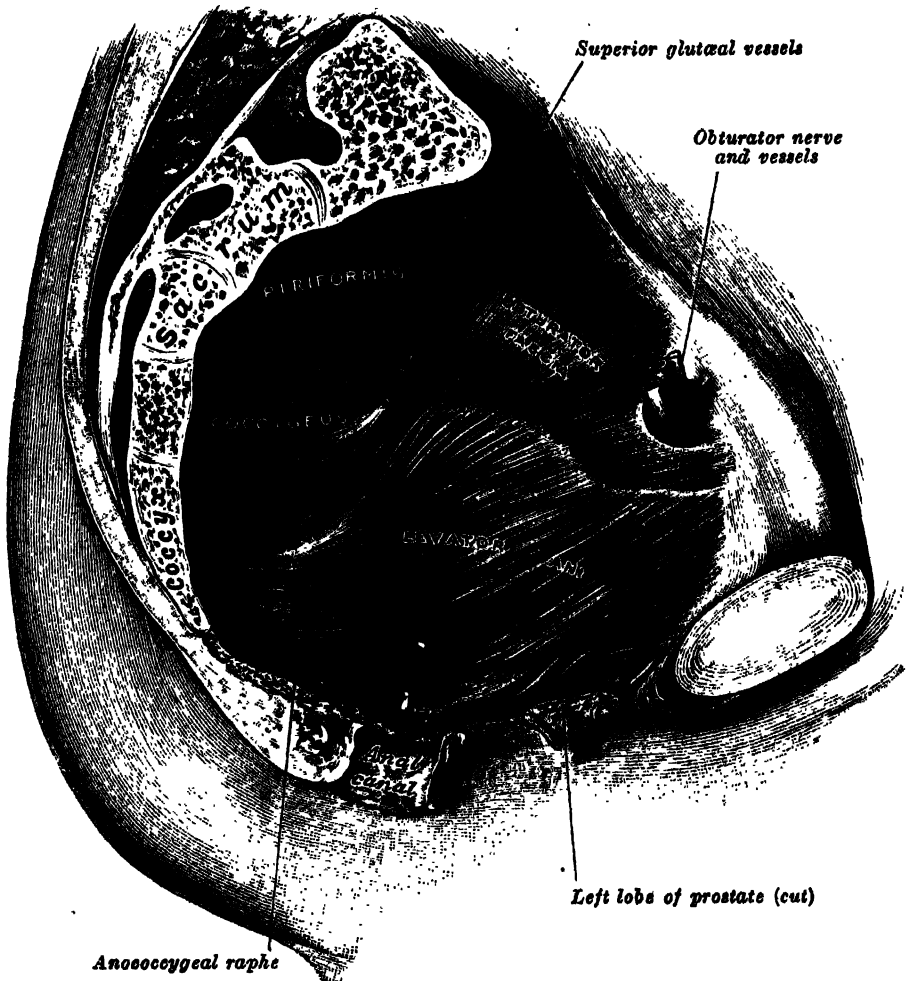


and vesiculæ seminales as the *rectovesical layer*; in the female this is perforated by the vagina. Its posterior portion, known as the *rectal layer*, passes to the side of the rectum; it forms a loose sheath for the rectum, but is firmly attached round the anal canal.

The *Levator ani* (fig. 543) is a broad, thin muscle; it is attached to the inner surface of the side of the lesser pelvis, and unites with its fellow of the opposite side to form the greater part of the floor of the pelvic cavity. It arises, in front, from the posterior surface of the superior ramus of the os pubis laterally to the symphysis; behind, from the inner surface of the spine of the ischium; and between these two points, from the obturator fascia. Posteriorly this fascial origin corresponds, more or less closely, with the tendinous arch of the pelvic fascia, but in front, the muscle arises from the fascia at a varying distance above the arch, in some cases reaching nearly as high as the canal

for the obturator vessels and nerve. The fibres pass downwards and backwards to the middle line of the floor of the pelvis; the posterior fibres are inserted into the side of the last two segments of the coccyx and into a median fibrous raphe (*anococcygeal raphe*), which extends between the coccyx and the margin of the anus. The middle fibres are inserted into the side of the anal canal, blending with those of the Sphincter muscles; lastly, the anterior fibres descend upon the side of the prostate to unite beneath it with the muscle

FIG. 548.—Left Levator ani from within.



of the opposite side, joining with the fibres of the Sphincter ani externus and Transversus perinei superficialis at the central tendinous point of the perinaeum.

The anterior portion is occasionally separated from the rest of the muscle by connective tissue. From this circumstance, as well as from its peculiar relation with the prostate, which it supports as in a sling, it has been described as a distinct muscle, under the name of *Levator prostatae*. In the female the anterior fibres of the Levator ani descend upon the side of the vagina.

The Levator ani may be divided into Iliococcygeus and Pubococcygeus.

The *Iliococcygeus* arises from the ischial spine and from the posterior part of the tendinous arch of the pelvic fascia, and is attached to the coccyx and anococcygeal raphe; it is usually thin, and may fall entirely or be largely replaced by fibrous tissue. An accessory slip at its posterior part is sometimes named the *Iliosacralis*. The *Pubococcygeus*

arises from the back of the os pubis and from the anterior part of the obturator fascia, and is directed backwards almost horizontally along the side of the anal canal. Between the coccyx and the anal canal the Pubococcygei come together and form a thick, fibromuscular layer lying on the raphe formed by the Iliococcygei. The fibres which form a sling for the rectum are named the *Puborectalis* or *Sphincter recti*; they rise from the lower part of the symphysis pubis, and from the superior fascia of the urogenital diaphragm; they meet with the corresponding fibres of the opposite side around the lower part of the rectum, and form for it a strong sling.

Symington* suggests that the Pubococcygeus should be named *Puboanal*, as it is doubtful if any of its fibres reach the coccyx.

Relations.—Its *upper* or *pelvic surface* is in relation with the diaphragmatic part of the pelvic fascia which separates it from the bladder, prostate, rectum, and peritoneum. Its *lower* or *perinæal surface* forms the medial boundary of the ischio-rectal fossa, and is covered by the inferior layer of the diaphragmatic part of the pelvic fascia (*anal fascia*). Its *posterior border* is free and separated from the Coccygeus muscle by areolar tissue. Its *anterior border* is separated from the muscle of the opposite side by a triangular space, through which the urethra, and in the female the urethra and vagina, pass from the pelvis.

Nerve-supply.—The Levator ani is supplied by a branch from the fourth sacral nerve and by a branch which is sometimes derived from the perinæal, sometimes from the inferior hæmorrhoidal, division of the pudendal nerve.

The Coccygeus (fig. 543) is situated behind the preceding. It is a triangular plane of muscular and tendinous fibres, arising by its apex from the spine of the ischium and sacrospinous ligament, and inserted by its base into the margin of the coccyx and into the side of the lowest piece of the sacrum. It assists the Levator ani and Piriformis in closing the posterior part of the outlet of the pelvis.

Nerve-supply.—The Coccygeus is supplied by a branch from the fourth and fifth sacral nerves.

Actions.—The Levatores ani constrict the lower end of the rectum and vagina. They are also muscles of forced expiration. The Coccygei pull forward and support the coccyx, after it has been pressed backwards during defæcation or parturition. The Levatores ani and Coccygei together form a muscular diaphragm which supports the pelvic viscera.

VI. MUSCLES OF THE PERINÆUM

The perinæum corresponds to the outlet of the pelvis. Its deep boundaries are—in front, the pubic arch and the ligamentum arcuatum pubis; behind, the tip of the coccyx; and on either side the inferior rami of the os pubis and ischium, and the sacrotuberous ligament. The space is somewhat lozenge-shaped and is limited on the surface of the body by the scrotum in front, by the buttocks behind, and by the medial sides of the thighs laterally. A line drawn transversely in front of the ischial tuberosities divides the space into two portions. The posterior contains the termination of the anal canal, and is known as the *anal region*; the anterior contains the external urogenital organs, and is termed the *urogenital region*.

The muscles of the perinæum may therefore be divided into two groups :

1. Those of the anal region.
2. Those of the urogenital region : A, In the male ; B, In the female.

1. MUSCLES OF THE ANAL REGION

Corrugator cutis ani. Sphincter ani externus. Sphincter ani internus.

The **superficial fascia** is very thick, areolar in texture, and contains much fat in its meshes. On either side a pad of fatty tissue extends deeply between the Levator ani and Obturator internus into a space known as the *ischio-rectal fossa*.

* *Journal of Anatomy and Physiology*, vol. xvi.

The deep fascia forms the lining of the ischio-rectal fossa; it comprises the anal fascia, and the portion of obturator fascia below the origin of Levator ani.

Ischio-rectal fossa.—The fossa is somewhat prismatic in shape, with its base directed to the surface of the perinæum, and its apex at the line of meeting of the obturator and anal fasciæ. It is bounded medially by the Sphincter ani externus and the anal fascia; laterally, by the tuberosity of the ischium and the obturator fascia; anteriorly, by the fascia of Colles covering the Transversus perinæi superficialis, and by the fascia of the urogenital diaphragm; posteriorly, by the Glutæus maximus and the sacrotuberous ligament. Crossing the space transversely are the inferior hæmorrhoidal vessels and nerves; at the posterior part are the perinæal and perforating cutaneous branches of the pudendal plexus; while from the anterior part the posterior scrotal (or labial) vessels and nerves emerge. The internal pudendal vessels and pudendal nerve lie on the lateral wall of the fossa, in Alcock's canal. The fossa is filled with fatty tissue, across which numerous fibrous bands extend from side to side.

Applied Anatomy.—Abscess in the ischio-rectal fossa commonly occurs; it is most often the result of infection from the bowel, and is especially prone to occur in tuberculous subjects; occasionally it follows perforation by a foreign body which has been swallowed, such as a fish bone. The abscess may bulge at the side of the anus, at the border of Glutæus maximus, or against the rectal wall. There is great pain on defæcation. On examining the bowel, fullness on the side of the abscess may be detected. If left to itself the pus will find exit through the skin, or into the rectum between the two Sphincters; and the condition will degenerate into one of the varieties of fistula, owing to the constant pull of the Sphincter ani externus preventing closure of the walls of the cavity. These abscesses should be opened at the earliest possible moment, as they tend to track and burrow widely into the soft fat in the fossa, and also in the subcutaneous tissues. An incision should be made tangential to the anus over the region of the ischio-rectal fossa, and should then be converted into a T, by making a second incision laterally at right angles to it, so that the wound may be kept open and may heal up from the bottom. Frequently, however, in spite of care, a fistula ensues which requires division of the Sphincter ani externus for its cure.

The Corrugator cutis ani.—Around the anus is a thin stratum of involuntary muscular fibres which radiate from the orifice. Medially the fibres fade off into the submucous tissue; laterally they blend with the true skin. By its contraction the skin around the anus is raised into ridges.

The Sphincter ani externus (fig. 544) is a flat plane of muscular fibres, elliptical in shape and intimately adherent to the skin surrounding the anus. It measures from 8 to 10 cm. in length and is about 2.5 cm. in width opposite the anus. It consists of two portions, superficial and deep. The *superficial portion*, constituting the chief part of the muscle, arises from a narrow tendinous band, the *anococcygeal raphe*, which stretches from the tip of the coccyx to the posterior margin of the anus; it forms two flattened planes of muscular tissue, which encircle the anus and meet in front to be inserted into the central tendinous point of the perinæum, joining with the Transversus perinæi superficialis, the Levator ani, and the Bulbocavernosus. The *deep portion* forms a complete sphincter to the anal canal. Its fibres surround the canal, closely applied to the Sphincter ani internus, and in front blend with the other muscles at the central point of the perinæum. In a considerable proportion of cases the fibres decussate in front of the anus, and are continuous with the Transversi perinæi superficiales. Posteriorly, they are not attached to the coccyx, but are continuous with those of the opposite side behind the anal canal. The upper edge of the muscle is ill-defined, since fibres are given off from it to join the Levator ani.

Nerve-supply.—A branch from the fourth sacral and twigs from the inferior hæmorrhoidal branch of the pudendal supply the muscle.

Actions.—The action of this muscle is peculiar. 1. It is normally in a state of tonic contraction, and having no antagonistic muscle it keeps the anal canal and orifice closed. 2. It can be put into a condition of greater contraction under the influence of the will, so as more firmly to occlude the anal aperture. 3. Taking its fixed point at the coccyx, it helps to fix the central point of the perinæum.

The **Sphincter ani internus** is a muscular ring which surrounds about 2.5 cm. of the anal canal; its inferior border is in contact with, but separate from, the **Sphincter ani externus**. It is about 5 mm. thick, and is formed by an aggregation of the involuntary circular fibres of the intestine. Its lower border is about 6 mm. from the orifice of the anus.

Actions.—Its action is entirely involuntary. It helps the **Sphincter ani externus** to occlude the anal aperture.

2. A. MUSCLES OF THE UROGENITAL REGION IN THE MALE (fig. 544)

Transversus perinæi superficialis.

Ischiocavernosus.

Bulbocavernosus.

Transversus perinæi profundus.

Sphincter urethræ membranaceæ.

Superficial fascia.—The superficial fascia of this region consists of two layers, superficial and deep.

The *superficial layer* is thick, loose, areolar in texture, and contains a variable amount of fat in its meshes. In front, it is continuous with the dartos tunic of the scrotum; behind, with the subcutaneous areolar tissue surrounding the anus; and, on either side, with the same fascia on the medial sides of the thighs. In the middle line, it is adherent to the skin of the raphe and to the deep layer of the superficial fascia.

The *deep layer of superficial fascia* (fascia of Colles) (fig. 542) is thin, aponeurotic in structure, and of considerable strength, serving to bind down the muscles of the root of the penis. It is continuous, in front, with the dartos tunic, the deep fascia of the penis, the fascia of the spermatic cord, and Scarpa's fascia upon the anterior wall of the abdomen; on either side it is attached to the margins of the rami of the os pubis and ischium, laterally to the crus penis and as far back as the tuberosity of the ischium; posteriorly, it curves round the **Transversus perinæi superficiales** to join the lower margin of the inferior fascia of the urogenital diaphragm. In the middle line, it is connected with the superficial fascia and with the median septum of the **Bulbocavernosus**. At its posterior part this fascia sends upwards from its deep surface a medial septum, which incompletely separates the posterior portion of the subjacent space into two.

The *central tendinous point of the perinæum*.—This is a fibrous point in the middle line of the perinæum, between the urethra and anus, and about 1.25 cm. in front of the latter. At this point six muscles converge and are attached: viz. the **Sphincter ani externus**, the **Bulbocavernosus**, the two **Transversi perinæi superficiales**, and the anterior fibres of the two **Levatores ani**.

The **Transversus perinæi superficialis** is a narrow muscular slip, which passes more or less transversely across the perinæal space in front of the anus. It is often feebly developed, and is sometimes absent. It arises by tendinous fibres from the medial and anterior part of the tuberosity of the ischium, and, running medialwards, is inserted into the central tendinous point of the perinæum, joining in this situation with the muscle of the opposite side, with the **Sphincter ani externus** behind, and with the **Bulbocavernosus** in front. In some cases, the fibres of the deeper layer of the **Sphincter ani externus** decussate in front of the anus and are continued into this muscle. Occasionally it gives off fibres, which join with the **Bulbocavernosus** of the same side.

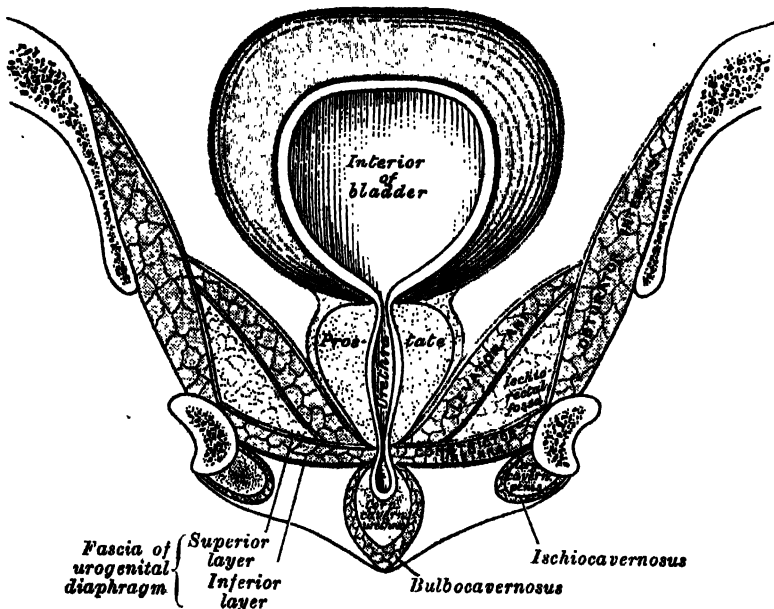
Actions.—The simultaneous contraction of the two muscles serves to fix the central tendinous point of the perinæum.

The **Bulbocavernosus** (*Ejaculator urinæ*) is placed in the middle line of the perinæum, in front of the anus, and consists of two symmetrical parts, united along the median line by a tendinous raphe. It arises from the central tendinous point of the perinæum and from the median raphe in front. Its fibres diverge like the barbs of a quill-pen; the most posterior form a thin layer, which is lost on the inferior fascia of the urogenital diaphragm; the middle fibres encircle the bulb and adjacent parts of the corpus cavernosum urethræ, and are inserted into a strong aponeurosis on the upper part of the corpus cavernosum urethræ; the anterior fibres spread out over the side of the corpus

Between the muscles just examined a triangular space exists, bounded medially by the Bulbocavernosus, laterally by the Ischiocavernosus, and behind by the Transversus perinæi superficialis; the floor is formed by the inferior fascia of the urogenital diaphragm. Running from behind forwards in the space are the posterior scrotal vessels and nerves, and the perinæal branch of the posterior femoral cutaneous nerve; the transverse perinæal artery courses along its posterior boundary on the Transversus perinæi superficialis.

The deep fascia of the urogenital region forms an investment for the Transversus perinæi profundus and the Sphincter urethræ membranaceæ, but within it lie also the deep vessels and nerves of this part, the whole forming a transverse septum which is known as the *urogenital diaphragm*. From its shape this part of the deep fascia is sometimes termed the *triangular ligament*, and it is stretched almost horizontally across the pubic arch, so as to close the anterior part of the pelvic outlet. It consists of two dense membranous laminae (fig. 545), which are united along their posterior borders, but are

FIG. 545.—Coronal section of anterior part of pelvis, through the pubic arch. Seen from in front. (Diagrammatic.)



separated in front by intervening structures. The superficial of these two layers, the *inferior fascia of the urogenital diaphragm* (superficial layer of the triangular ligament), is triangular in shape, and about 4 cm. in depth. Its apex is directed forwards, and is separated from the arcuate pubic ligament by an oval opening for the transmission of the deep dorsal vein of the penis. Its lateral margins are attached on either side to the inferior rami of the os pubis and ischium, above the crus penis. Its base is directed towards the anus, and connected to the central tendinous point of the perinæum. It is continuous with the deep layer of the superficial fascia behind the Transversus perinæi superficialis, and with the inferior layer of the diaphragmatic part of the pelvic fascia (anal fascia). It is perforated, about 2.5 cm. below the symphysis pubis, by the urethra, the aperture for which is circular and about 6 mm. in diameter; by the arteries and nerves to the bulb and the ducts of the bulbo-urethral glands close to the urethra; by the deep arteries of the penis, one on either side close to the pubic arch and about halfway along the attached margin of the fascia; by the dorsal arteries and nerves of the penis near the apex of the fascia. Its base is also perforated by the posterior scrotal vessels and nerves, while between its apex and the arcuate pubic ligament the deep dorsal vein of the penis passes upwards into the pelvis.

If the inferior fascia of the urogenital diaphragm be detached, the following structures will be seen between it and the superior fascia: the deep dorsal vein of the penis, the membranous portion of the urethra, the *Transversus perinæi profundus* and *Sphincter urethræ membranaceæ* muscles, the bulbourethral glands and their ducts, the pudendal vessels and dorsal nerves of the penis, the arteries and nerves of the urethral bulb, and a plexus of veins.

The *superior fascia of the urogenital diaphragm* (deep layer of the triangular ligament) is continuous with the obturator fascia and stretches across the pubic arch. If the obturator fascia be traced medially after leaving the *Obturator internus* muscle, it will be found attached by some of its deeper or anterior fibres to the inner margin of the pubic arch, while its superficial or posterior fibres pass over this attachment to become continuous with the superior fascia of the urogenital diaphragm. Behind, this layer of the fascia is continuous with the inferior fascia of the urogenital diaphragm and with the fascia of Colles: in front it is continuous with the fascial sheath of the prostate, and is fused with the inferior fascia to form the *transverse ligament of the pelvis*.

The *Transversus perinæi profundus* arises from the inferior rami of the ischium and runs to the median line, where it interlaces in a tendinous raphe with its fellow of the opposite side. It lies in the same plane as the *Sphincter urethræ membranaceæ*; formerly the two muscles were described together as the *Constrictor urethræ*.

The *Sphincter urethræ membranaceæ* surrounds the membranous portion of the urethra, and is enclosed in the fascia of the urogenital diaphragm. Its external fibres arise from the junction of the inferior rami of the os pubis and ischium, to the extent of 1.25 or 2 cm., and from the neighbouring fasciæ. They arch across the front of the urethra and bulbourethral glands, pass round the urethra, and behind unite with the muscle of the opposite side, by means of a tendinous raphe. Its internal fibres form a continuous circular investment for the membranous urethra.

Actions.—The muscles of both sides act together as a sphincter, compressing the membranous portion of the urethra. During the transmission of fluids they, like the *Bulbocavernosus*, are relaxed, and only come into action at the end of the process to eject the last drops.

Nerve-supply.—The perineal branch of the pudendal nerve supplies this group of muscles.

2. B. MUSCLES OF THE UROGENITAL REGION IN THE FEMALE (fig. 546)

Transversus perinæi superficialis.

Ischiocavernosus.

Bulbocavernosus.

Transversus perinæi profundus.

Sphincter urethræ membranaceæ.

The *Transversus perinæi superficialis* in the female is a narrow muscular slip, which arises by a small tendon from the inner and fore part of the tuberosity of the ischium, and is inserted into the central tendinous point of the perinæum, joining in this situation with the muscle of the opposite side, the *Sphincter ani externus* behind, and the *Bulbocavernosus* in front.

Action.—The simultaneous contraction of the two muscles serves to fix the central tendinous point of the perinæum.

The *Bulbocavernosus* (*Sphincter vaginæ*) surrounds the orifice of the vagina. It covers the lateral parts of the vestibular bulbs, and is attached posteriorly to the central tendinous point of the perinæum, where it blends with the *Sphincter ani externus*. Its fibres pass forwards on either side of the vagina, to be inserted into the corpora cavernosa clitoridis, a fasciculus crossing over the body of the organ so as to compress the deep dorsal vein.

Actions.—The *Bulbocavernosus* diminishes the orifice of the vagina. The anterior fibres contribute to the erection of the clitoris by the compression of its deep dorsal vein.

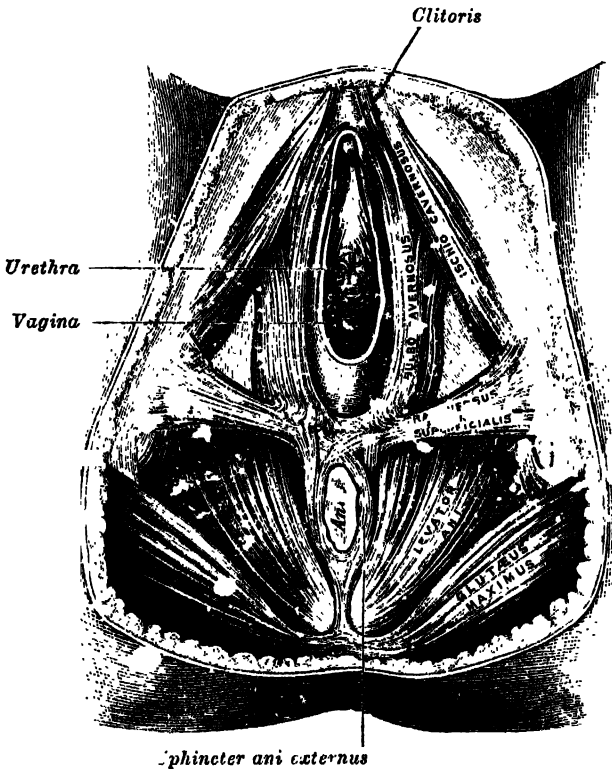
The *Ischiocavernosus* (*Erector clitoridis*), smaller than the corresponding muscle in the male, covers the unattached surface of the crus clitoridis. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity

of the ischium, behind the crus clitoridis; from the surface of the crus; and from the adjacent portion of the ramus of the ischium. The muscular fibres end in an aponeurosis which is inserted into the sides and under surface of the crus clitoridis.

Actions.—The Ischiocavernosus compresses the crus clitoridis and retards the return of blood through the veins, and thus serves to maintain the clitoris erect.

The *fascia of the urogenital diaphragm* in the female is not so strong as in the male. It is attached to the pubic arch, its apex being connected with the arcuate pubic ligament. It is divided in the middle line by the aperture of the vagina; with the external coat of which it blends, and in front of this it is perforated by the urethra. Its posterior border is continuous with the deep layer of the superficial fascia around the Transversus perinæi superficialis.

FIG. 546.—Muscles of the female perinæum. (Modified from a drawing by Peter Thompson.)



Like the corresponding fascia in the male, it consists of two layers, between which are to be found the following structures: the deep dorsal vein of the clitoris, a portion of the urethra, the Transversus perinæi profundus and Sphincter urethræ membranaceæ muscles, the greater vestibular glands and their ducts, the internal pudendal vessels and the dorsal nerves of the clitoris, the arteries and nerves of the bulbi vestibuli, and a plexus of veins.

The Transversus perinæi profundus arises from the inferior rami of the ischium and runs across to the side of the vagina.

The Sphincter urethræ membranaceæ, like the corresponding muscle in the male, consists of external and internal fibres. The external fibres arise on either side from the margin of the inferior ramus of the os pubis. They are directed across the pubic arch in front of the urethra, and pass round it to blend with the muscular fibres of the opposite side, between the urethra and vagina. The innermost fibres encircle the lower end of the urethra.

Nerve-supply.—The muscles of this group are supplied by the perinæal branch of the pudendal nerve.

FASCIÆ AND MUSCLES OF THE UPPER EXTREMITY

The muscles of the upper extremity are divisible into the following groups :

- I. Muscles connecting the upper extremity with the vertebral column.
- II. Muscles connecting the upper extremity to the anterior and lateral thoracic walls.
- III. Muscles of the shoulder.
- IV. Muscles of the arm.
- V. Muscles of the forearm.
- VI. Muscles of the hand.

I. MUSCLES CONNECTING THE UPPER EXTREMITY WITH THE VERTEBRAL COLUMN

Trapezius.	Rhomboideus major.
Latissimus dorsi.	Rhomboideus minor.
Levator scapulæ.	

The superficial fascia of the back forms a layer of considerable thickness and strength, and contains a quantity of granular fat. It is continuous with the general superficial fascia.

The deep fascia is a dense fibrous layer, attached above to the superior nuchal line of the occipital bone ; in the middle line it is fixed to the ligamentum nuchæ and supraspinal ligament, and to the spinous processes of all the vertebræ below the seventh cervical : laterally, in the neck it is continuous with the fascia colli ; over the shoulder it is attached to the spine of the scapula and to the acromion, and is continued downwards over the Deltoidæus to the arm ; on the thorax it is continuous with the deep fascia of the axilla and chest, and on the abdomen with that covering the abdominal muscles ; below, it is attached to the crest of the ilium.

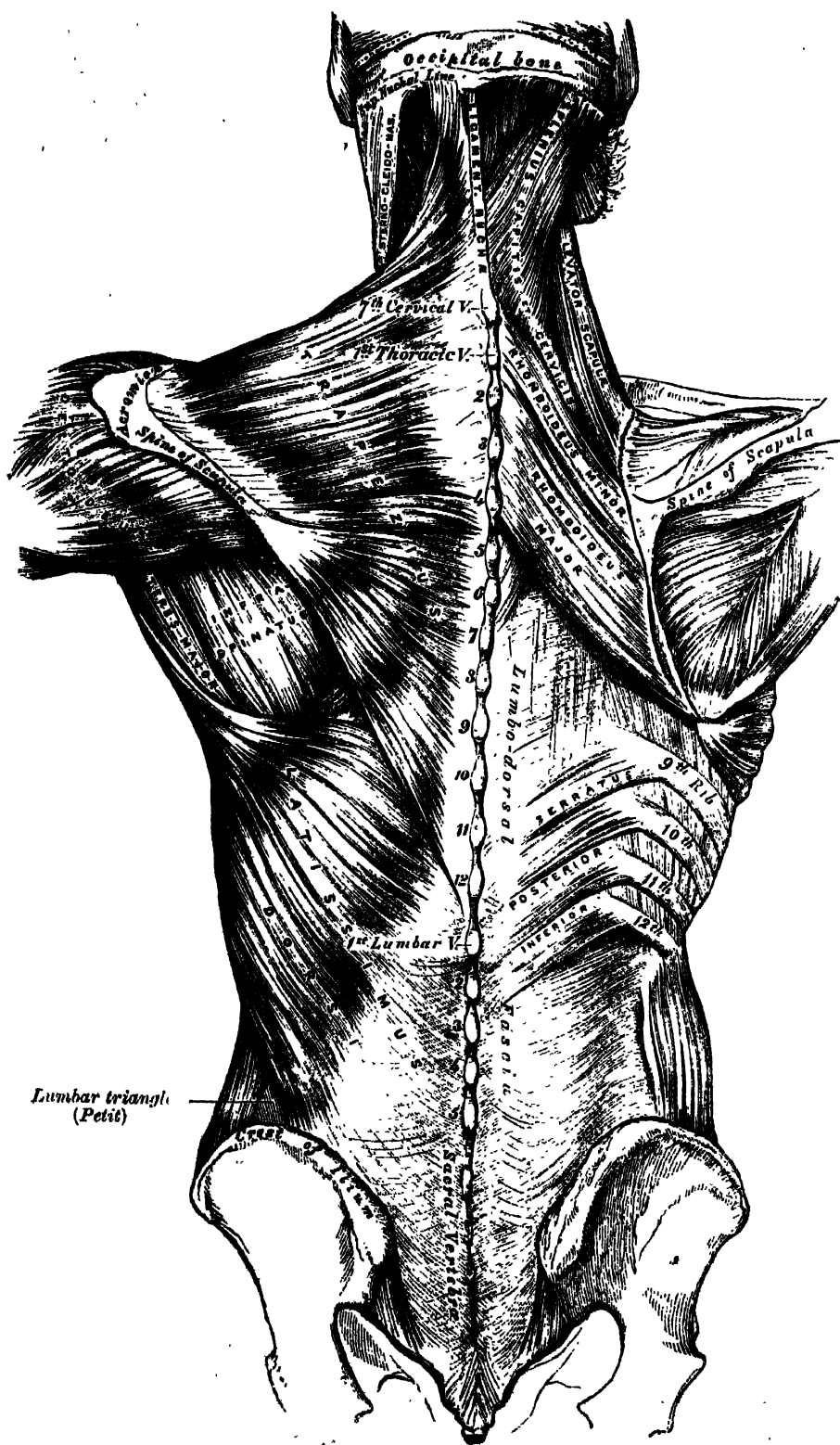
The **Trapezius** (fig. 547) is a flat, triangular muscle, covering the back of the neck and shoulder. It arises from the medial third of the superior nuchal line of the occipital bone, the external occipital protuberance, the ligamentum nuchæ, the spinous process of the seventh cervical, and the spinous processes of all the thoracic vertebræ, and the corresponding portion of the supraspinal ligament. The superior fibres proceed downwards and lateralwards, the inferior upwards and lateralwards, and the middle horizontally ; the superior fibres are inserted into the posterior border of the lateral third of the clavicle ; the middle fibres into the medial margin of the acromion and the superior lip of the posterior border of the spine of the scapula ; the inferior fibres converge and end in an aponeurosis, which glides over the smooth triangular surface on the medial end of the spine of the scapula, a bursa being interposed, and is inserted into a tubercle at the apex of this smooth triangular surface. The upper part of the Trapezius is connected to the occipital bone by a thin fibrous lamina, firmly adherent to the skin ; the middle part arises by a broad semi-elliptical aponeurosis, which reaches from the sixth cervical to the third thoracic vertebra ; the lower part arises by short tendinous fibres. The two Trapezius muscles together resemble a trapezium, or quadrangle ; two angles corresponding to the shoulders ; a third to the occipital protuberance ; and the fourth to the spinous process of the twelfth thoracic vertebra.*

The clavicular insertion of this muscle varies in extent : it sometimes reaches as far as the middle of the clavicle, and occasionally blends with or overlaps the posterior edge of the Sternocleidomastoideus.

The **Latissimus dorsi** (fig. 547) is a large triangular, flat muscle, which covers the lumbar region and the lower half of the thoracic region ; but its fibres converge to a narrow tendon of insertion. It arises by tendinous fibres from the spinous processes of the lower six thoracic vertebræ in front of the Trapezius, and from the posterior layer of the lumbodorsal fascia (p. 444), by which it is attached to the spines of the lumbar and sacral vertebræ to the

* The two muscles cover the back of the neck and shoulders like a monk's cowl, and therefore the Trapezius is sometimes termed the *Musculus cucullaris*.

FIG. 547.—Muscles connecting the upper extremity to the vertebral column.



supraspinal ligament; and to the posterior part of the crest of the ilium. In addition, it arises by muscular fibres from the external lip of the crest of the ilium lateral to the margin of the Sacrospinalis, and from the three or four lower ribs by fleshy digitations which are interposed between similar processes of the Obliquus abdominis externus (fig. 532, p. 457). From this extensive origin the fibres pass in different directions, the upper ones horizontally, the middle obliquely upwards, and the lower almost vertically upwards, so as to converge and form a thick fasciculus, the upper part of which crosses, and usually receives a few fibres from, the inferior angle of the scapula. The muscle curves around the lower border of the Teres major, and is twisted upon itself, so that the superior fibres become at first posterior and then inferior, and the ascending fibres at first anterior and then superior. It ends in a quadrilateral tendon, about 7 cm. long, which passes in front of the tendon of the Teres major, and is inserted into the bottom of the intertubercular sulcus of the humerus, giving an expansion to the deep fascia of the arm; its insertion extends higher on the humerus than that of the tendon of the Pectoralis major. The lower border of its tendon is united with that of the Teres major, the surfaces of the two tendons being separated near their insertions by a bursa; another bursa is sometimes interposed between the muscle and the inferior angle of the scapula.

A muscular slip, the *axillary arch*, varying from 7 to 10 cm. in length, and from 5 to 15 mm. in breadth, occasionally springs from the upper edge of the Latissimus dorsi about the middle of the posterior fold of the axilla, and crosses the axilla in front of the axillary vessels and nerves, to join the under surface of the tendon of the Pectoralis major, the Coracobrachialis, or the fascia over the Biceps brachii. This axillary arch crosses the axillary artery, just above the spot usually selected for the application of a ligature, and may mislead the surgeon during the operation. It is present in about seven per cent. of subjects and may be easily recognised by the direction of its fibres.

A fibrous slip usually passes from the lower border of the tendon of the Latissimus dorsi, near its insertion, to the long head of the Triceps brachii. This is occasionally muscular, and is the representative of the *Dorsoepitrochlearis brachii* of apes.

The lower part of the lateral margin of the Latissimus dorsi is separated from the Obliquus externus abdominis by a small triangular interval, the *lumbar triangle* (of Petit), the base of which is formed by the iliac crest, and its floor by the Obliquus internus abdominis. Another triangle, known as the *triangle of auscultation*, is situated behind the scapula. It is bounded above by the Trapezius, below by the Latissimus dorsi, and laterally by the vertebral border of the scapula; the floor is partly formed by the Rhomboideus major. If the scapula be drawn forwards by folding the arms across the chest, and the trunk bent forwards, parts of the sixth and seventh ribs and the interspace between them become subcutaneous and available for auscultation.

Nerves.—The Trapezius is supplied by the accessory nerve, and by branches from the third and fourth cervical nerves; the Latissimus dorsi by the fifth, sixth, and seventh cervical nerves through the thoracodorsal (long subscapular) nerve.

The **Rhomboideus major** (fig. 547) arises by tendinous fibres from the spinous processes of the second, third, fourth, and fifth thoracic vertebræ and the supraspinal ligament. The fibres of the muscle are directed downwards and lateralwards and are inserted into the vertebral border of the scapula between the triangular surface of the root of the spine and the inferior angle. Usually the insertion is an indirect one, the muscular fibres ending in a tendinous arch which is fixed at its ends to the two points mentioned and joined to the vertebral border by a thin membrane; occasionally the arch is incomplete, and some of the muscular fibres are then inserted directly into the scapula.

The **Rhomboideus minor** (fig. 547) arises from the lower part of the ligamentum nuchæ and from the spinous processes of the seventh cervical and first thoracic vertebræ; it is inserted into the base of the triangular smooth surface at the root of the spine of the scapula. It is usually separated from the Rhomboideus major by a slight interval, but the adjacent margins of the two muscles are occasionally united.

The **Levator scapulae** (fig. 547) is situated at the back and side of the neck. It arises by tendinous slips from the transverse processes of the atlas and Axis and from the posterior tubercles of the transverse processes of the

third and fourth cervical vertebræ. It is inserted into the vertebral border of the scapula, between the medial angle and the triangular smooth surface at the root of the spine.

Nerves.—The Rhomboidei are supplied by the fifth cervical through the dorsal scapular nerve; the Levator scapulæ by the third and fourth cervical nerves, and frequently by a branch from the dorsal scapular.

Actions.—When the whole Trapezii is in action it retracts the scapula and braces back the shoulder; if the head be fixed, the upper part of the muscle will elevate the point of the shoulder, as in supporting weights; when the lower fibres contract they assist in depressing the scapula. The middle and lower fibres of the muscle rotate the scapula. If the shoulders be fixed, the Trapezii, acting together, will draw the head directly backwards; or if only one act, the head is drawn to the corresponding side.

When the Latissimus dorsi acts upon the humerus, it depresses and draws it backwards, and at the same time rotates it inwards. It is the muscle which is principally employed in giving a downward blow, as in felling a tree or in sabre practice. If the arm be fixed, the muscle may act in various ways upon the trunk: thus, it may raise the lower ribs and assist in forcible inspiration; or, if both arms be fixed, the two muscles may assist the abdominal muscles and Pectorales in suspending and drawing the trunk upwards and forwards, as in climbing.

The Rhomboidei carry the inferior angle backwards and upwards, thus producing a slight rotation of the scapula upon the side of the chest, the Rhomboideus major acting especially on the inferior angle of the scapula, through the tendinous arch by which it is inserted. The Rhomboidei, acting together with the middle and inferior fibres of the Trapezii, will retract the scapula.

If the head be fixed, the Levator scapulæ raises the medial angle of the scapula; if the shoulder be fixed, the muscle inclines the neck to the corresponding side and rotates it in the same direction.

II. MUSCLES CONNECTING THE UPPER EXTREMITY TO THE ANTERIOR AND LATERAL THORACIC WALLS

Pectoralis major.
Pectoralis minor.

Subclavius.
Serratus anterior.

The **superficial fascia** of the anterior thoracic region is continuous with that of the neck and upper extremity above, and of the abdomen below. It encloses the mamma and gives off numerous septa which pass into the gland to support its various lobes. From the fascia over the front of the mamma, fibrous processes pass forwards to the integument and mammary papilla; these were called by Sir A. Cooper the *ligamenta suspensoria*.

The **pectoral fascia** is a thin lamina, covering the surface of the Pectoralis major, and sending numerous prolongations between its fasciuli; it is attached, in the middle line, to the front of the sternum; above, to the clavicle; laterally and below, it is continuous with the fascia of the shoulder, axilla, and thorax. It is very thin over the upper part of the Pectoralis major, but thicker in the interval between it and the Latissimus dorsi, where it closes in the axillary space and forms the *axillary fascia*; this divides at the lateral margin of the Latissimus dorsi into two layers, one of which passes in front of, and the other behind this muscle; these proceed as far as the spinous processes of the thoracic vertebræ, to which they are attached. As the fascia leaves the lower edge of the Pectoralis major to cross the floor of the axilla it sends a layer upwards under cover of the muscle; this lamina splits to envelop the Pectoralis minor, and at the upper edge of this muscle is continuous with the coracoclavicular fascia. The hollow of the armpit, seen when the arm is abducted, is produced mainly by the traction of this fascia on the axillary floor, and hence the lamina is sometimes named the *suspensory ligament* of the axilla. At the lower part of the thoracic region the deep fascia is well developed, and is continuous with the fibrous sheath of the Rectus abdominis.

Applied Anatomy.—In cases of suppuration in the axilla, the pus is prevented from extending downwards by the axillary fascia, and therefore tends to spread upwards, beneath the pectoral muscles, towards the root of the neck. Early evacuation of the pus

is therefore necessary. The incision should be made midway between the anterior and posterior axillary folds, so as to avoid the lateral thoracic and subscapular vessels, and the edge of the knife should be directed away from the axillary vessels.

The **Pectoralis major** (fig. 548) is a thick, triangular muscle situated at the upper and front part of the chest. It arises from the anterior surface of the sternal half of the clavicle; from half the breadth of the anterior surface of the sternum, as low down as the attachment of the cartilage of the sixth or

FIG. 548.—Superficial muscles of the chest and front of the arm.



seventh rib; from the cartilages of all the true ribs, with the exception, frequently, of the first, or seventh, or both, and from the aponeurosis of the *Obliquus externus abdominis*. From this extensive origin the fibres converge towards their insertion; those arising from the clavicle pass obliquely downwards and lateralwards, and are usually separated from the rest by a slight interval; those from the lower part of the sternum, and the cartilages of the lower true ribs, run upwards and lateralwards; while the middle fibres pass horizontally. They all end in a flat tendon, about 5 cm. broad, which is inserted into the crest of the greater tubercle of the humerus. This tendon consists of two laminae, placed one in front of the other, and usually blended together

below. The anterior lamina, the thicker, receives the clavicular and the uppermost sternal fibres; they are inserted in the same order as that in which they arise: that is to say, the most lateral of the clavicular fibres are inserted at the upper part of the anterior lamina; the uppermost sternal fibres pass down to the lower part of the lamina, which extends as low as the tendon of the Deltoides and joins with it. The posterior lamina of the tendon receives the attachment of the greater part of the sternal portion and the deep fibres, i.e. those from the costal cartilages. These deep fibres, and particularly those from the lower costal cartilages, turn backwards successively behind and reach a higher level than the superficial and upper ones, so that the tendon appears to be twisted. The posterior lamina of the tendon reaches higher on the humerus than the anterior, and gives off an expansion which covers the intertubercular sulcus and blends with the capsule of the shoulder-joint. From the deepest fibres of this lamina at its insertion an expansion is given off which lines the intertubercular sulcus, while from the lower border of the tendon a third expansion passes downwards to the fascia of the arm.

Relations.—In front of the Pectoralis major are the skin, superficial fascia, Platysma, anterior and middle supraclavicular nerves, mamma, and deep fascia; its *posterior surface* is in contact with the sternum, ribs and costal cartilages, coracoclavicular fascia, Subclavius, Pectoralis minor, Serratus anterior, and Intercostales; it forms the anterior wall of the axillary space, and covers the axillary vessels and nerves and the upper parts of the Biceps brachii and Coracobrachialis. Its *upper border* is separated from the Deltoides by a slight interspace, the *deltoideopectoral triangle*, or *infraclavicular fossa*, in which the cephalic vein and deltoid branch of the thoraco-acromial artery lie. Its *lower border* forms the anterior fold of the axilla; it is separated from the Latissimus dorsi by a considerable interval at the medial wall of the axilla; but the two muscles gradually converge towards the lateral wall of the space.

The coracoclavicular fascia (costocoracoid membrane) is a strong fascia situated under cover of the clavicular portion of the Pectoralis major. It occupies the interval between the Pectoralis minor and Subclavius, and protects the axillary vessels and nerves. Traced upwards, it splits to enclose the Subclavius, and is attached to the clavicle, in front of and behind the muscle; the layer behind the muscle fuses with the deep cervical fascia and with the sheath of the axillary vessels. Medially, it blends with the fascia covering the first two intercostal spaces, and is attached also to the first rib medial to the origin of the Subclavius. Laterally, it is thick and dense, and is attached to the coracoid process. The portion extending from the first rib to the coracoid process is often stronger than the rest, and is sometimes called the *costocoracoid ligament*. Below this, the fascia is thin; it splits to ensheath the Pectoralis minor; and from the lower border of this muscle is continued downwards to join the axillary fascia, and lateralwards to unite with the fascia covering the short head of the Biceps brachii. The coracoclavicular fascia is pierced by the cephalic vein, thoraco-acromial artery and vein, and lateral anterior thoracic nerve.

The Pectoralis minor (fig. 549) is a thin, triangular muscle, situated at the upper part of the thorax, beneath the Pectoralis major. It arises from the upper margins and outer surfaces of the third, fourth, and fifth ribs, near their cartilages, and from the aponeuroses covering the Intercostales externi; the fibres pass upwards and lateralwards, and converge to form a flat tendon, which is inserted into the medial border and upper surface of the coracoid process of the scapula.

Relations.—Its *anterior surface* is in relation with the Pectoralis major, the lateral anterior thoracic nerve, and the pectoral branch of the thoraco-acromial artery; its *posterior surface*, with the ribs, Intercostales externi, Serratus anterior, the axillary space, and the axillary vessels and brachial plexus of nerves. Its *upper border* is separated from the clavicle by a narrow triangular interval occupied by the coracoclavicular fascia, behind which are the axillary vessels and nerves. Running parallel with the *lower border* of the muscle is the lateral thoracic artery, and piercing the muscle is the medial anterior thoracic nerve.

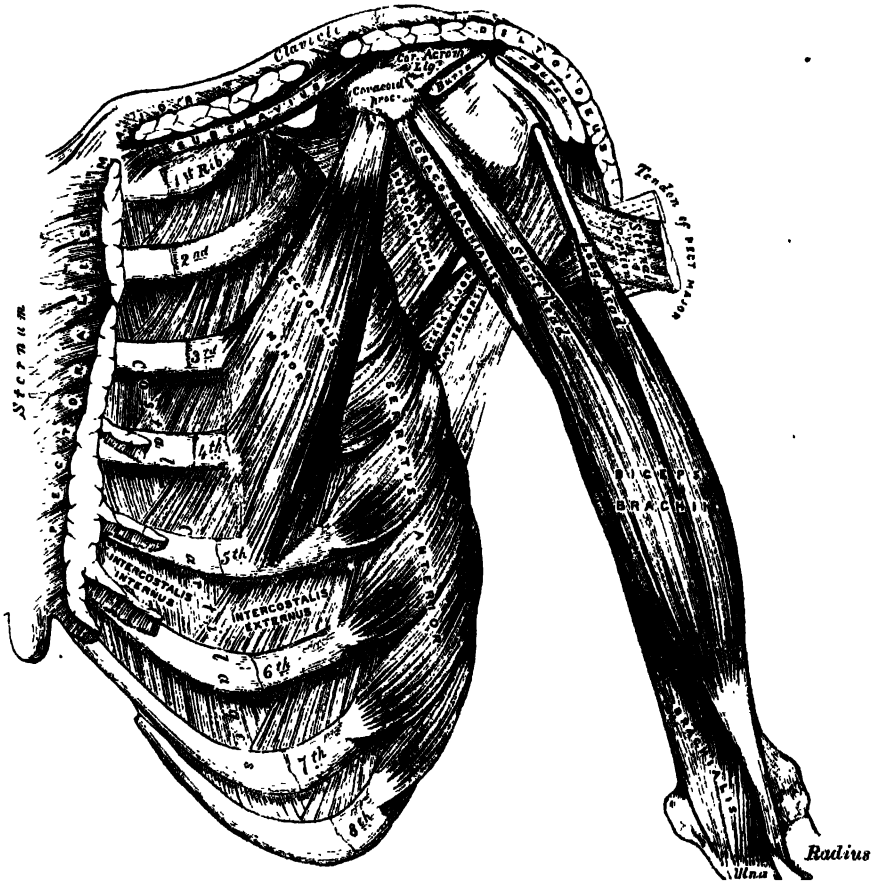
The Subclavius (fig. 549) is a small triangular muscle, placed between the clavicle and first rib. It arises by a short, thick tendon from the first rib and its cartilage at their junction, in front of the costoclavicular ligament;

the fleshy fibres proceed obliquely upwards and lateralwards, to be inserted into the groove on the under surface of the clavicle between the costoclavicular and coracoclavicular ligaments.

Relations.—Its *posterior surface* is separated from the first rib by the subclavian vessels and brachial plexus of nervos. Its *anterior surface* is separated from the Pectoralis major by the coracoclavicular fascia, which, with the clavicle, forms an osseofibrous sheath for the muscle.

The **Serratus anterior** (Serratus magnus) (fig. 549) is a muscular sheet, situated between the ribs and scapula at the upper and lateral part of the

FIG. 549.—Deep muscles of the chest and front of the arm.



chest. It arises by fleshy slips or digitations from the outer surfaces and superior borders of the upper eight or nine ribs, and from the aponeuroses covering the intervening Intercostales. Each digitation (except the first) arises from the corresponding rib; the first springs from the first and second ribs, and from the fascia covering the first intercostal space. The lower four slips interdigitate with the upper five slips of the Obliquus externus abdominis. From this extensive attachment the fibres pass backwards, closely applied to the chest-wall, and reach the vertebral border of the scapula, and are inserted into its ventral surface in the following manner. The first digitation is inserted into a triangular area on the ventral surface of the medial angle. The next two or three digitations spread out to form a thin, triangular sheet, the base of which is directed backwards and is inserted into nearly the whole length of the ventral surface of the vertebral border. The lower five or six digitations converge to form a fan-shaped mass, the apex of which is inserted, by muscular

and tendinous fibres, into a triangular impression on the ventral surface of the inferior angle.

Nerves.—The Pectoralis major is supplied by the medial and lateral anterior thoracic nerves; through these nerves the muscle receives filaments from all the spinal nerves entering into the formation of the brachial plexus. The Pectoralis minor receives its fibres from the eighth cervical and first thoracic nerves through the medial anterior thoracic nerve. The Subclavius is supplied by a filament from the fifth and sixth cervical nerves. The Serratus anterior is supplied by the long thoracic, which is derived from the fifth, sixth, and seventh cervical nerves.

Actions.—If the arm has been raised by the Deltoides, the Pectoralis major will, conjointly with the Latissimus dorsi and Teres major, depress it to the side of the chest. If acting alone, it adducts and draws forwards the arm, bringing it across the front of the chest, and at the same time rotates it inwards. The Pectoralis minor depresses the point of the shoulder, drawing the scapula downwards and medialwards towards the thorax, and throwing the inferior angle backwards. The Subclavius depresses the shoulder, carrying it downwards and forwards. When the arms are elevated and fixed, all three muscles act upon the ribs, drawing them upwards and expanding the chest, and thus assisting in forced inspiration. The Serratus anterior, as a whole, carries the scapula forwards, and at the same time raises the vertebral border of the bone. It is, therefore, concerned in the action of pushing. Its lower and stronger fibres move the lower angle forwards and assist the Trapezius in rotating the bone at the sternoclavicular joint, and thus aid this muscle in raising the acromion and supporting weights upon the shoulder. It is also an assistant to the Deltoides in raising the arm, inasmuch as during the action of this latter muscle it fixes the scapula and so steadies the glenoid cavity on which the head of the humerus rotates. After the Deltoides has raised the arm to a right angle with the trunk, the Serratus anterior and the Trapezius, by rotating the scapula, raise the arm into an almost vertical position. It is possible that when the shoulders are fixed the lower fibres of the Serratus anterior may assist in raising and everting the ribs; but it is not the important inspiratory muscle it was formerly believed to be.

Applied Anatomy.—When the Serratus anterior is paralysed, the vertebral border, and especially the lower angle of the scapula, leave the ribs and stand out prominently on the surface, giving a peculiar 'winged' appearance to the back (p. 271). The patient is unable to raise the arm, and an attempt to do so is followed by a further projection of the lower angle of the scapula from the back of the thorax.

III. MUSCLES OF THE SHOULDER

Deltoides.
Subscapularis.
Supraspinatus.

Infraspinatus.
Teres minor.
Teres major.

The deep fascia covering the Deltoides invests the muscle, and sends numerous septa between its fasciculi. In front, it is continuous with the pectoral fascia; behind, where it is thick and strong, with the fascia infraspinata; above, it is attached to the clavicle, the acromion, and the spine of the scapula; below, it is continuous with the brachial fascia.

The Deltoides (fig. 548) is a thick, triangular muscle, which covers the shoulder-joint. It arises from the anterior border and upper surface of the lateral third of the clavicle; from the lateral margin and upper surface of the acromion, and from the lower lip of the posterior border of the spine of the scapula, as far back as the triangular surface at its medial end. The fibres converge towards their insertion, the middle passing vertically, the anterior inclining backwards, and the posterior forwards; they unite in a thick tendon which is inserted into the deltoid tuberosity on the middle of the lateral side of the body of the humerus. At its insertion the tendon gives off an expansion to the deep fascia of the arm. This muscle is remarkably coarse in texture, and the part arising from the acromion consists of oblique fibres; these arise in a bipennate manner from the sides of tendinous septa, generally four in number, which pass downwards from the acromion into the muscle. These oblique fibres are inserted into similar tendinous septa, generally

three in number, which ascend from the insertion of the muscle and alternate with the descending septa. The portions of the muscle arising from the clavicle and spine of the scapula are not arranged in this manner, but are inserted into the margins of the inferior tendon.

Relations.—Its *superficial surface* is in relation with the skin, the superficial and deep fasciæ, Platysma, posterior supraclavicular, and lateral brachial cutaneous nerves. Its *deep surface* is separated from the articular capsule of the shoulder-joint by a large bursa, and covers the coracoid process, coraco-acromial ligament, Pectoralis minor, Coracobrachialis, both heads of the Biceps brachii, the tendon of the Pectoralis major, the insertions of the Supraspinatus, Infraspinatus, and Teres minor, the long and lateral heads of the Triceps brachii, the humeral circumflex vessels, the axillary nerve, and the upper part of the body of the humerus. Its *anterior border* is separated at its upper part from the Pectoralis major by the deltoideopectoral triangle in which the cephalic vein and deltoid branch of the thoraco-acromial artery lie; lower down the two muscles are in close contact. Its *posterior border* rests on the Infraspinatus and Triceps brachii.

Nerves.—The Deltoideus is supplied by the fifth and sixth cervical nerves through the axillary nerve.

Actions.—The Deltoideus raises the arm from the side, so as to bring it at right angles with the trunk. Its anterior fibres, assisted by the Pectoralis major, draw the arm forwards; and its posterior fibres, aided by the Teres major and Latissimus dorsi, draw it backwards.

Applied Anatomy.—The Deltoideus is very liable to atrophy, and in this condition dislocation of the shoulder-joint is simulated, as there is flattening of the shoulder and apparent prominence of the acromion; the distance also between the acromion and the head of the bone is increased, and the tips of the fingers can be inserted between them. Atrophy of the Deltoideus may be due to disuse, such as follows chronic arthritis or permanent injury of the shoulder-joint. It also frequently results from degenerations occurring in the medulla spinalis, or injury to the axillary nerve ('crutch-palsy'). The Deltoideus, Supraspinatus, and Infraspinatus often escape in myopathic atrophies affecting the other muscles of the upper arm or shoulder in young persons.

The subscapular fascia is a thin membrane attached to the entire circumference of the subscapular fossa, and giving origin by its deep surface to some of the fibres of the Subscapularis.

The Subscapularis (fig. 549) is a large triangular muscle which fills the subscapular fossa, and arises from its medial two-thirds and from the lower two-thirds of the groove on the axillary border of the scapula. Some fibres arise from tendinous laminae which intersect the muscle and are attached to ridges on the bone; others from an aponeurosis, which separates the muscle from the Teres major and the long head of the Triceps brachii. The fibres pass lateralwards, and, gradually converging, end in a tendon which is inserted into the lesser tubercle of the humerus and the front of the capsule of the shoulder-joint. The tendon of the muscle is separated from the neck of the scapula by a large bursa, which communicates with the cavity of the shoulder-joint through an aperture in the articular capsule.

Relations.—The *anterior surface* of this muscle forms a considerable part of the posterior wall of the axilla, and is in relation with the Serratus anterior, Coracobrachialis, and Biceps brachii, the axillary vessels and brachial plexus of nerves, and the subscapular vessels and nerves. Its *posterior surface* is in relation with the scapula and the capsule of the shoulder-joint. Its *lower border* is in contact with the Teres major and Latissimus dorsi.

Nerves.—The Subscapularis is supplied by the fifth and sixth cervical nerves through the subscapular nerves.

Actions.—The Subscapularis rotates the head of the humerus inwards; when the arm is raised, it draws the humerus forwards and downwards. It is a powerful defence to the front of the shoulder-joint.

The fascia supraspinata completes the osseofibrous case in which the Supraspinatus muscle is contained, and its deep surface gives origin to some of the fibres of the muscle. It is thick medially, but thinner laterally under the coraco-acromial ligament.

The **Supraspinatus** (fig. 550) occupies the supraspinatous fossa, arising from its medial two-thirds, and from the fascia supraspinata. The muscular fibres converge to a tendon, which crosses the upper part of the shoulder-joint, and is inserted into the highest of the three impressions on the greater tubercle of the humerus; the tendon is intimately adherent to the capsule of the shoulder-joint.

The **fascia infraspinata** is a dense fibrous membrane, covering the Infraspinatus muscle and fixed to the circumference of the infraspinatus fossa; its deep surface gives origin to some fibres of that muscle. It is intimately attached to the deltoid fascia along the overlapping border of the Deltoides.

FIG. 550.—Muscles on the dorsum of the scapula, and the Triceps brachii.



The **Infraspinatus** (fig. 550) is a thick triangular muscle, which occupies the chief part of the infraspinatous fossa; it arises by fleshy fibres from the medial two-thirds of the fossa, and by tendinous fibres from the ridges on its surface: it also arises from the fascia infraspinata which covers it and separates it from the Teretes major and minor. The fibres converge to a tendon, which glides over the lateral border of the spine of the scapula, and, passing across the posterior part of the capsule of the shoulder-joint, is inserted into the middle impression on the greater tubercle of the humerus. The tendon of this muscle is sometimes separated from the capsule of the shoulder-joint by a bursa which may communicate with the joint-cavity.

The **Teres minor** (fig. 550) is a narrow, elongated muscle, which arises from the dorsal surface of the axillary border of the scapula for the upper two-thirds of its extent, and from two aponeurotic laminae, one of which separates it from the Infraspinatus, the other from the Teres major. Its fibres run obliquely upwards and lateralwards; the upper ones end in a tendon which is inserted into the lowest of the three impressions on the greater tubercle of the humerus; the lower fibres are inserted directly into the humerus immediately below this

impression and just above the origin of the lateral head of the *Triceps brachii*. The tendon of this muscle passes across, and is united with, the posterior part of the capsule of the shoulder-joint.

The **Teres major** (fig. 550) is a thick, somewhat flattened muscle, which arises from the oval area on the dorsal surface of the inferior angle of the scapula, and from the fibrous septa interposed between the muscle and the *Teres minor* and *Infraspinatus*; the fibres are directed upwards and laterally and end in a flat tendon, about 5 cm. long, which is inserted into the crest of the lesser tubercle of the humerus. At its insertion the tendon lies behind that of the *Latissimus dorsi*, from which it is separated by a bursa, the two tendons being, however, united along their lower borders for a short distance.

Nerves.—The *Supraspinatus* and *Infraspinatus* are supplied by the fifth and sixth cervical nerves through the suprascapular nerve; the *Teres minor*, by the fifth cervical, through the axillary nerve; and the *Teres major*, by the fifth and sixth cervical, through the lowest subscapular nerve.

Actions.—The *Supraspinatus* assists the *Deltoides* in raising the arm from the side of the trunk and fixes the head of the humerus in the glenoid cavity. The *Infraspinatus* and *Teres minor* rotate the head of the humerus outwards; they also assist in carrying the arm backwards. One of the most important uses of these three muscles is to protect the shoulder-joint, the *Supraspinatus* supporting it above, and the *Infraspinatus* and *Teres minor* behind. The *Teres major* assists the *Latissimus dorsi* in drawing the previously raised humerus downwards and backwards, and in rotating it inwards; when the arm is fixed it may assist the *Pectorales* and the *Latissimus dorsi* in drawing the trunk forwards.

IV. MUSCLES OF THE ARM

Coracobrachialis.
Biceps brachii.

Brachialis.
Triceps brachii.

The **brachial fascia** or deep fascia of the arm is continuous with that covering the *Deltoides* and the *Pectoralis major*; it forms a thin, loose sheath for the muscles of the arm, and sends septa between them; it is composed of fibres disposed in a circular or spiral direction, and connected together by vertical and oblique fibres. It is thin over the *Biceps brachii*, but thicker where it covers the *Triceps brachii*, and over the epicondyles of the humerus: it is strengthened by fibrous aponeuroses, derived from the *Pectoralis major* and *Latissimus dorsi* medially, and from the *Deltoides* laterally. On either side it gives off a strong intermuscular septum, which is attached to the corresponding supracondylar ridge and epicondyle of the humerus.

The **lateral intermuscular septum** extends from the lower part of the crest of the greater tubercle of the humerus, along the lateral supracondylar ridge, to the epicondyle; it is blended with the tendon of the *Deltoides*, gives attachment to the *Triceps brachii* behind, to the *Brachialis*, *Brachioradialis*, and *Extensor carpi radialis longus* in front, and is perforated by the radial nerve and *arteria profunda brachii*. The **medial intermuscular septum**, thicker than the preceding, extends from the lower part of the crest of the lesser tubercle of the humerus below the *Teres major*, along the medial supracondylar ridge to the epicondyle; it is blended with the tendon of the *Coracobrachialis*, and affords attachment to the *Triceps brachii* behind and the *Brachialis* in front. It is perforated by the ulnar nerve, the superior ulnar collateral artery, and the posterior branch of the inferior ulnar collateral artery.

At the elbow, the deep fascia is attached to the epicondyles of the humerus and the olecranon of the ulna, and is continuous with the deep fascia of the forearm. Just below the middle of the arm, on its medial side, is an oval opening in the deep fascia, which transmits the basilic vein and some lymphatic vessels.

The **Coracobrachialis** (fig. 549) is situated at the upper and medial part of the arm. It arises from the apex of the coracoid process, in common with the tendon of the short head of the *Biceps brachii*, and by muscular fibres from the upper 10 cm. of this tendon; it is inserted by means of a flat tendon into

an impression at the middle of the medial surface and border of the body of the humerus between the origins of the *Triceps brachii* and *Brachialis*.

Relations.—It is perforated by the musculocutaneous nerve, and is in relation, in *front*, with the *Pectoralis major* above, and at its insertion with the brachial vessels and median nerve which cross it; *behind*, with the tendons of the *Subscapularis*, *Latissimus dorsi*, and *Teres major*, the medial head of the *Triceps brachii*, the humerus, and the anterior humeral circumflex vessels; by its *medial border*, with the third part of the axillary artery, the upper part of the brachial artery, the median and musculocutaneous nerves; by its *lateral border*, with the *Biceps brachii* and *Brachialis*.

The ***Biceps brachii*** (fig. 549), a long fusiform muscle placed on the front of the arm, has received its name from the circumstance that it has two heads of origin. The *short head* arises by a thick flattened tendon from the apex of the coracoid process, in common with the *Coracobrachialis*. The *long head* arises by a long narrow tendon from the supraglenoid tuberosity at the upper margin of the glenoid cavity, and is continuous with the glenoidal labrum. This latter tendon, enclosed in a special sheath of the synovial stratum of the articular capsule of the shoulder-joint, arches over the head of the humerus; it emerges from the joint through an opening in the articular capsule close to its humeral attachment and descends in the intertubercular sulcus; it is retained in the sulcus by the transverse humeral ligament and by a fibrous prolongation from the tendon of the *Pectoralis major*. Each tendon is succeeded by an elongated muscular belly, and the two bellies, although closely applied to each other, can be readily separated until within about 7·5 cm. of the elbow-joint. Here they end in a flattened tendon, which is inserted into the rough posterior portion of the tuberosity of the radius, a bursa being interposed between the tendon and the front part of the tuberosity. As the tendon of the muscle approaches the radius it is twisted on itself, so that its anterior surface becomes lateral and is applied to the tuberosity of the radius at its insertion. Opposite the bend of the elbow the tendon gives off, from its medial side, a broad aponeurosis, the *lacertus fibrosus* or *bicipital fascia*, which passes obliquely downwards and medialwards across the brachial artery and is continuous with the deep fascia covering the origins of the *Flexor* muscles of the forearm (fig. 548).

A third head to the *Biceps brachii* is occasionally found, arising at the upper and medial part of the *Brachialis*, with which it is blended, and inserted into the *lacertus fibrosus* and medial side of the tendon of the muscle; in most cases this additional slip lies behind the brachial artery. In some instances the third head consists of two slips, which pass down, one in front of, the other behind the artery.

Relations.—The *Biceps brachii* is overlapped above by the *Pectoralis major* and *Deltoides*; in the rest of its extent it is covered by the fasciæ and skin. Above, it rests on the shoulder-joint and upper part of the humerus; below, it lies on the *Brachialis*, the musculocutaneous nerve, and the *Supinator*. Its *medial border* is in relation with the *Coracobrachialis*, and overlaps the brachial vessels and median nerve; its *lateral border*, with the *Deltoides* and *Brachioradialis*.

The ***Brachialis*** (*Brachialis anticus*) (fig. 549) covers the front of the elbow-joint and the lower half of the humerus. It arises from the lower half of the front of the humerus, commencing above at the insertion of the *Deltoides*, which it embraces by two angular processes, and extending below to within 2·5 cm. of the margin of the articular surface. It also arises from the intermuscular septa, but more extensively from the medial than the lateral; it is separated from the lower part of the lateral intermuscular septum by the *Brachioradialis* and *Extensor carpi radialis longus*. Its fibres converge to a thick tendon, which is inserted into the tuberosity of the ulna and the rough depression on the anterior surface of the coronoid process.

Relations.—It is in relation, in *front*, with the *Biceps brachii*, the brachial vessels, musculocutaneous and median nerves; *behind*, with the humerus and articular capsule of the elbow-joint; by its *medial border*, with the *Pronator teres*, and with the medial intermuscular septum which separates it from the *Triceps brachii* and the ulnar nerve; by its *lateral border*, with the radial nerve, radial recurrent artery, the *Brachioradialis*, and *Extensor carpi radialis longus*.

Nerves.—The *Coracobrachialis*, *Biceps brachii*, and *Brachialis* are supplied by the musculocutaneous nerve; the *Brachialis* usually receives an additional filament

from the radial nerve. The Coracobrachialis receives its supply primarily from the seventh cervical, the Biceps brachii and Brachialis from the fifth and sixth cervical nerves.

Actions.—The Coracobrachialis draws the humerus forwards and medialwards and at the same time assists in retaining the head of the bone in contact with the glenoid cavity. The Biceps brachii is a flexor of the elbow and, to a less extent, of the shoulder: it is also a powerful supinator of the radius and serves to render tense the deep fascia of the forearm by means of the lacertus fibrosus. The Brachialis is a flexor of the forearm, and forms an important defence to the elbow-joint. When the forearm is fixed, the Biceps brachii and Brachialis flex the arm upon the forearm, as in efforts of climbing.

Applied Anatomy.—The long tendon of the Biceps brachii is sometimes dislocated from the intertubercular sulcus. When this occurs, the arm is fixed in a position of abduction, but the head of the humerus can be felt in its proper position. The tendon can generally be replaced by flexing the forearm on the arm and rotating the limb. Rupture of the long tendon of the Biceps brachii may also take place.

The **Triceps brachii** (fig. 550), situated on the back of the arm, is of large size, and arises by three heads (long, lateral, and medial), hence its name.

The *long head* arises by a flattened tendon from the infraglenoid tuberosity of the scapula, being blended at its upper part with the capsule of the shoulder-joint; the muscular fibres pass downwards between the other two heads of the muscle, and join with them in the tendon of insertion.

The *lateral head* has a narrow origin from the posterior surface of the body of the humerus, extending from the insertion of the Teres minor to the upper part of the sulcus for the radial nerve, and from the lateral border of the humerus and the lateral intermuscular septum; the fibres from this origin converge towards the tendon of insertion.

The *medial head* arises from the posterior surface of the body of the humerus, below the sulcus for the radial nerve; it is narrow and pointed above, and extends from the insertion of the Teres major to within 2.5 cm. of the trochlea humeri; it also arises from the medial border of the bone and from the back of the whole length of the medial intermuscular septum. Some of the fibres are directed downwards to the olecranon, while others converge to the tendon of insertion.

The *tendon* of insertion of the Triceps brachii begins about the middle of the muscle: it consists of two aponeurotic laminae, one of which covers the back of the lower half of the muscle; the other is more deeply seated in the substance of the muscle. After receiving the attachment of the muscular fibres, the two lamellae join together above the elbow, and are inserted, for the most part, into the posterior portion of the upper surface of the olecranon; a band of fibres is, however, continued downwards, on the lateral side, over the Anconæus, to blend with the deep fascia of the forearm.

The long head of the Triceps brachii descends between the Teres minor and Teres major, dividing the triangular space between these two muscles and the humerus into two smaller spaces, one triangular, the other quadrangular (fig. 550). The triangular space contains the scapular circumflex vessels; it is bounded by the Teres minor above, the Teres major below, and the scapular head of the Triceps laterally. The quadrangular space transmits the posterior humeral circumflex vessels and the axillary nerve; it is bounded by the Teres minor and capsule of the shoulder-joint above, the Teres major below, the long head of the Triceps brachii medially, and the humerus laterally.

The *Subanconæus* is the name given to a few fibres which spring from the deep surface of the lower part of the Triceps brachii, and are inserted into the posterior part of the articular capsule of the elbow-joint.

Nerves.—The Triceps brachii is supplied by the seventh and eighth cervical nerves through the radial nerve.

Actions.—The Triceps brachii is the great extensor muscle of the forearm, and is the direct antagonist of the Biceps brachii and Brachialis. When the arm is extended, the long head of the muscle may assist the Teres major and Latissimus dorsi in drawing the humerus backwards and in adducting it to the thorax. The

long head supports the under part of the shoulder-joint. The Subanconæus draws up the posterior part of the articular capsule of the elbow-joint during extension of the forearm.

Applied Anatomy.—The insertion of the Triceps brachii into the deep fascia of the forearm is of importance in the operation of excision of the elbow, and should always be carefully preserved. By means of it the patient is enabled to extend the forearm, a movement which would otherwise be accomplished mainly by gravity—that is to say, by allowing the forearm to drop by its own weight.

V. MUSCLES OF THE FOREARM

The **antibrachial fascia** (deep fascia of the forearm), continuous above with the brachial fascia, is a dense investment, which forms a general sheath for the muscles in this region; it is attached, behind, to the olecranon and dorsal border of the ulna, and gives off from its deep surface numerous inter-muscular septa. It gives origin to muscular fibres, especially at the upper part of the medial and lateral sides of the forearm, and forms the boundaries of a series of cone-shaped cavities, in which the muscles are contained; transverse septa are given off both on the volar and dorsal surfaces of the forearm, separating the deep from the superficial layers of muscles. It is much thicker on the dorsal than on the volar surface, and at the lower than at the upper part of the forearm, and is strengthened above by tendinous fibres derived from the Biceps brachii in front, and from the Triceps brachii behind. Over the flexor tendons as they approach the wrist it is especially thickened, and forms the volar carpal ligament. This is continuous with the transverse carpal ligament, and forms a sheath for the tendon of the Palmaris longus which passes over the transverse carpal ligament to be inserted into the palmar aponeurosis. Behind, near the wrist-joint, it is thickened by the addition of many transverse fibres, and forms the dorsal carpal ligament. Apertures exist in the fascia for the passage of vessels and nerves; one of these apertures, of large size and situated at the front of the elbow, transmits a communicating branch between the superficial and deep veins.

The antibrachial or forearm muscles consist of a volar and a dorsal group.

1. VOLAR ANTIBRACHIAL MUSCLES

These muscles are divided for convenience of description into two groups, superficial and deep.

(a) *Superficial Group* (fig. 551)

Pronator teres.	Palmaris longus.
Flexor carpi radialis.	Flexor carpi ulnaris.
Flexor digitorum sublimis.	

The muscles of this group take origin from the medial epicondyle of the humerus by a common tendon; they receive additional fibres from the antibrachial fascia near the elbow, and from the septa which pass from this fascia between the individual muscles.

The **Pronator teres** has a humeral and an ulnar head of origin. The *humeral head*, the larger and more superficial, arises immediately above the medial epicondyle, and from the tendon common to the origin of the other muscles; also from the intermuscular septum between it and the Flexor carpi radialis and from the antibrachial fascia. The smaller *ulnar head* arises from the medial side of the coronoid process of the ulna, and joins the humeral head at an acute angle. The median nerve enters the forearm between the two heads of the muscle, and is separated from the ulnar artery by the ulnar head. The muscle passes obliquely across the forearm, and ends in a flat tendon, which is inserted into a rough impression at the middle of the lateral surface of the body of the radius. The lateral border of the muscle forms

the medial boundary of a triangular hollow, which is situated in front of the elbow-joint and contains the brachial artery, median nerve, and tendon of the Biceps brachii.

Applied Anatomy.—This muscle, when suddenly brought into active use, as in the game of lawn-tennis, is apt to be strained, producing slight swelling, tenderness, and pain on putting the muscle into action. This is known as 'lawn-tennis arm.'

The **Flexor carpi radialis** lies on the medial side of the Pronator teres. It arises from the medial epicondyle by the common tendon, from the anti-brachial fascia, and from the intermuscular septa between it and the adjacent muscles. Slender and aponeurotic in structure at its commencement, it increases in size, and ends in a long tendon which passes through a canal in the lateral part of the transverse carpal ligament and through a groove on the greater multangular bone; the groove is converted into a canal by fibrous tissue and lined by a mucous sheath. The tendon is inserted into the base of the second metacarpal bone, and sends a slip to the base of the third metacarpal bone. In the lower part of the forearm the radial artery lies between the tendon of this muscle and that of the Brachioradialis.

FIG. 551.—Front of the left forearm. Superficial muscles.



The **Palmaris longus** is a slender, fusiform muscle, lying on the medial side of the Flexor carpi radialis. It arises from the medial epicondyle of the humerus by the common tendon, from the intermuscular septa between it and the adjacent muscles, and from the anti-brachial fascia. It ends in a long slender tendon which passes over the upper part of the transverse carpal ligament and is inserted into the anterior surface of the lower half of this ligament and into the central part of the palmar aponeurosis, frequently sending a tendinous slip to the short muscles of the thumb. Just above the wrist, the median nerve lies deep to the tendon.

This muscle is often absent, and is subject to very considerable variations: it may be tendinous above and muscular below, or muscular in the centre with a tendon above and below; or it may consist of two muscular bundles with a central tendon; or finally it may consist solely of a tendinous band.

The **Flexor carpi ulnaris** lies along the ulnar side of the forearm. It arises by two heads, humeral and ulnar, connected by a tendinous arch, beneath which the ulnar nerve passes downwards and the posterior ulnar recurrent artery upwards. The *humeral head* is very small and arises from the medial epicondyle of the humerus by the common tendon; the *ulnar head* arises from the medial margin of the olecranon and from the upper two-thirds of the dorsal border of the ulna by an aponeurosis common to it and the Extensor carpi ulnaris and Flexor digitorum profundus; and from

the intermuscular septum between it and the Flexor digitorum sublimis. The fibres end in a tendon, which occupies the anterior part of the lower half of the muscle and is inserted into the pisiform bone, whence it is prolonged to the hamate and fifth metacarpal bones by the pisohamate and pisometacarpal

ligaments; it is also attached by a few fibres to the transverse carpal ligament. The ulnar vessels and nerve lie on the lateral side of the tendon of insertion of this muscle.

The **Flexor digitorum sublimis** is dorsal to the preceding muscle; it is the largest of the muscles of the superficial group, and arises by two heads, humero-ulnar and radial. The *humero-ulnar head* arises from the medial epicondyle of the humerus by the common tendon, from the ulnar collateral ligament of the elbow-joint, from the intermuscular septa between it and the preceding muscles, and from the medial side of the coronoid process, above the ulnar origin of the Pronator teres. The *radial head*, a thin sheet of muscle, arises from the oblique line of the radius, extending from the radial tuberosity to the insertion of the Pronator teres. The muscle speedily separates into two planes of muscular fibres, superficial and deep: the superficial plane divides into two parts which end in tendons for the middle and ring fingers; the deep plane gives off a muscular slip to join that part of the superficial plane which is associated with the tendon of the ring finger, and then divides into two parts, which end in tendons for the index and little fingers. As the four tendons pass beneath the transverse carpal ligament into the palm of the hand, they are arranged in pairs, the superficial pair going to the middle and ring fingers, the deep pair to the index and little fingers. The tendons diverge from one another in the palm and form deep relations to the superficial volar arch and digital branches of the median and ulnar nerves. Opposite the bases of the first phalanges each tendon divides into two slips, to allow of the passage of the corresponding tendon of the Flexor digitorum profundus; the two slips then reunite and form a grooved channel for the reception of the accompanying tendon of the Flexor digitorum profundus. Finally the tendon divides and is inserted into the sides of the second phalanx about its middle.

(b) *Deep Group* (fig. 552)

Flexor digitorum profundus.

Flexor pollicis longus.

Pronator quadratus.

The **Flexor digitorum profundus** is situated on the ulnar side of the forearm, dorsal to the superficial flexors. It arises from the upper three-fourths of the volar and medial surfaces of the body of the ulna, embracing the insertion of the Brachialis above, and extending below to within a short distance of the Pronator quadratus. It also arises from a depression on the medial side of the coronoid process; by an aponeurosis from the upper three-fourths of the dorsal border of the ulna, in common with the Flexor and Extensor carpi ulnaris; and from the ulnar half of the interosseous membrane. The muscle ends in four tendons which run behind the transverse carpal ligament, dorsal to the tendons of the Flexor digitorum sublimis. The portion of the muscle for the index finger is usually distinct throughout, but the tendons for the middle, ring, and little fingers are connected together by areolar tissue and tendinous slips, as far as the palm of the hand. Opposite the first phalanges the tendons pass through the openings in the tendons of the Flexor digitorum sublimis, and are inserted into the bases of the last phalanges.

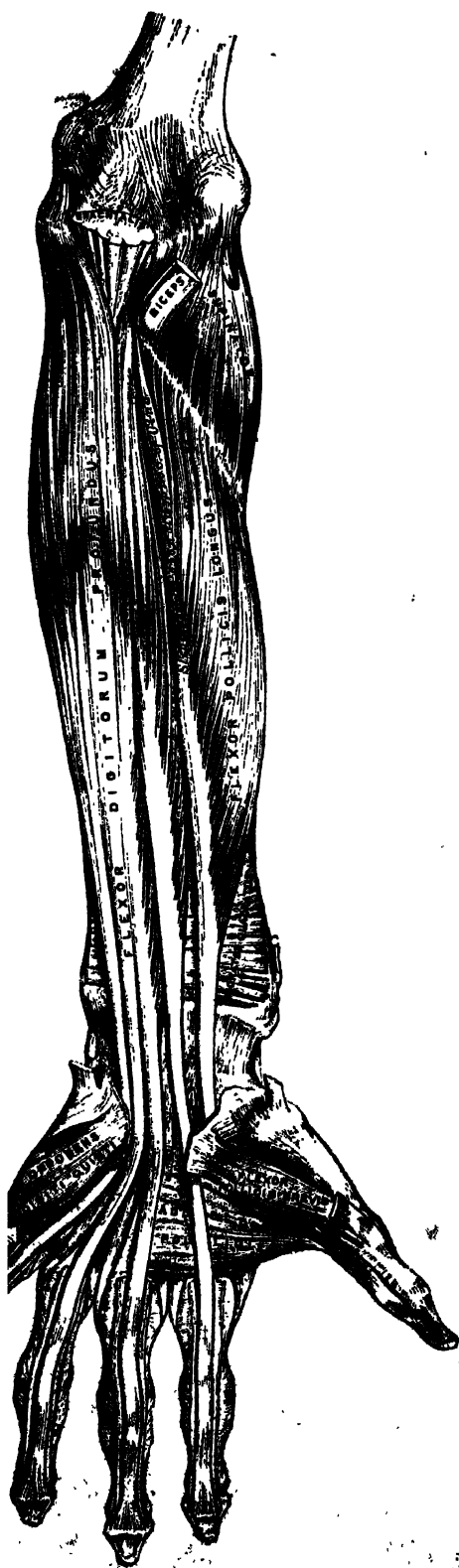
Four small muscles, the Lumbricales, are connected with the tendons of the Flexor digitorum profundus in the palm. They will be described with the muscles of the hand (p. 508).

Fibrous sheaths of the flexor tendons.—After leaving the palm, the tendons of the Flexores digitorum sublimis and profundus lie in osseo-aponeurotic canals (fig. 563, p. 507), formed behind by the phalanges and in front by fibrous bands, which arch across the tendons, and are attached on either side to the margins of the phalanges and to the volar accessory ligaments of the interphalangeal joints. Opposite the middle of the proximal and second phalanges the bands (*digital vaginal ligaments*) are very strong, and the fibres are transverse; but opposite the joints they are much thinner, and consist of *annular* and *cruciate* fibres. Each canal is lined by a mucous sheath, which is reflected on the contained tendons.

As the flexor tendons approach their insertions they are connected to the dorsal parts of the enclosing sheaths by triangular and thread-like bands

MYOLOGY

FIG. 552.—Front of the left forearm.
Deep muscles.



of the mucous sheaths. These bands, termed *vincula tendinea* (fig. 553), convey minute vessels to the tendons, and are of two kinds, (a) *vincula brevia* and (b) *vincula longa*.

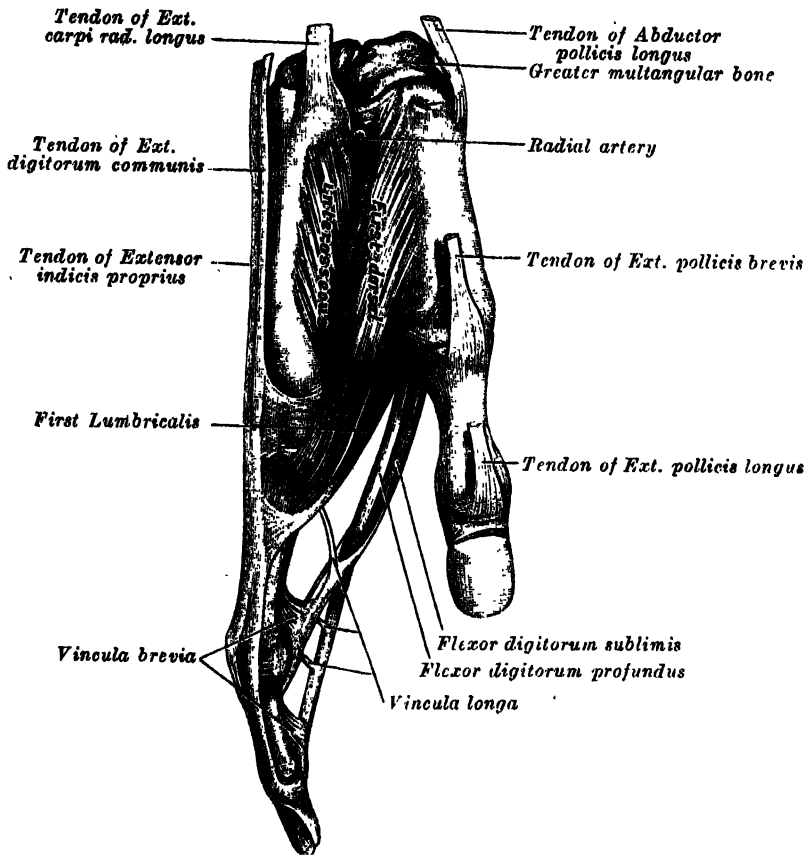
The *vincula brevia*, two in number in each finger, are triangular bands attached to the deep surfaces of the tendons close to their insertions; one connects the tendon of the Flexor digitorum sublimis to the front of the first interphalangeal joint and adjacent part of the first phalanx, and the other the tendon of the Flexor digitorum profundus to the front of the second interphalangeal joint and adjacent part of the second phalanx. The *vincula longa* are thread-like slips, of which two are usually attached to each tendon of the Flexor digitorum sublimis, and one to each tendon of the Flexor digitorum profundus. Those of the Flexor digitorum sublimis are connected to the slips of that tendon where these fold over the tendon of the Flexor digitorum profundus, and, passing one on either side of the latter tendon, are attached to the sheath at the lateral margins of the proximal third of the first phalanx. That of the tendon of the Flexor digitorum profundus is fixed to its tendon shortly after the latter has pierced the tendon of the Flexor digitorum sublimis. It runs upwards and backwards, perforates one of the two slips of the latter tendon, or passes between the two slips; thereafter it blends with the vinculum breve of the Flexor digitorum sublimis, and is attached to the sheath at the distal end of the first phalanx.

The Flexor pollicis longus is situated on the radial side of the forearm in the same plane as the Flexor digitorum profundus. It arises from the grooved volar surface of the body of the radius, extending from immediately below the tuberosity and oblique line, to within a short distance of the Pronator quadratus. It arises also from the adjacent part of the interosseous membrane, and generally by a fusiform fleshy slip

from the medial border of the coronoid process below the Flexor digitorum sublimis and Pronator teres, or from the medial epicondyle of the humerus. The fibres end in a flattened tendon, which passes behind the transverse carpal ligament, is then lodged between the lateral head of the Flexor pollicis brevis and the oblique part of the Adductor pollicis, and, entering an osseo-aponeurotic canal similar to those for the flexor tendons of the fingers, is inserted into the base of the distal phalanx of the thumb. The volar interosseous nerve and vessels descend on the front of the interosseous membrane between the Flexor pollicis longus and Flexor digitorum profundus.

The **Pronator quadratus** is a flat, quadrilateral muscle, extending across the front of the lower parts of the radius and ulna. It arises from the pronator

FIG. 553.—Tendons of forefinger, and vincula tendinea.



ridge on the lower part of the volar surface of the body of the ulna; from the medial part of the volar surface of the lower fourth of the ulna; and from a strong aponeurosis which covers the medial third of the muscle. The fibres pass lateralwards and slightly downwards, to be inserted into the lower fourth of the lateral border and the volar surface of the body of the radius; the deeper fibres are inserted into the triangular area above the ulnar notch of the radius.

Nerves.—All the muscles of the superficial layer are supplied by the median nerve, excepting the Flexor carpi ulnaris, which is supplied by the ulnar. The Pronator teres, the Flexor carpi radialis, and the Palmaris longus derive their supply primarily from the sixth cervical nerve; the Flexor digitorum sublimis from the seventh and eighth cervical and first thoracic nerves, and the Flexor carpi ulnaris from the eighth cervical and first thoracic. Of the deep layer, the Flexor digitorum profundus is supplied by the eighth cervical and first thoracic through

the ulnar nerve, and the volar interosseous branch of the median nerve. The *Flexor pollicis longus* and *Pronator quadratus* are supplied by the eighth cervical and first thoracic through the volar interosseous branch of the median nerve.

Actions.—These muscles act upon the forearm, wrist, and hand. The *Pronator teres* and *Pronator quadratus* rotate the radius upon the ulna, rendering the hand prone. The *Flexor carpi radialis* is a flexor and abductor of the wrist; it also assists in pronating the hand. The *Flexor carpi ulnaris* is a flexor and adductor of the wrist. The *Palmaris longus* tightens the palmar aponeurosis and flexes the wrist. All these muscles may assist in flexing the elbow. The *Flexor digitorum sublimis* flexes first the middle, and then the proximal, phalanges; it also assists in flexing the wrist and elbow. After the *Flexor sublimis* has bent the second phalanges, the *Flexor profundus* flexes the terminal ones; it also assists in flexing the wrist. The *Flexor pollicis longus* is a flexor of the phalanges of the thumb; it may assist in flexing the wrist.

2. DORSAL ANTIBRACHIAL MUSCLES

These muscles are divided for convenience of description into two groups, superficial and deep.

(a) *Superficial Group* (fig. 554)

<i>Brachioradialis.</i>	<i>Extensor digitorum communis.</i>
<i>Extensor carpi radialis longus.</i>	<i>Extensor digiti quinti proprius.</i>
<i>Extensor carpi radialis brevis.</i>	<i>Extensor carpi ulnaris.</i>
<i>Anconæus.</i>	

The ***Brachioradialis*** (*Supinator longus*) is the most superficial muscle on the radial side of the forearm. It arises from the upper two-thirds of the lateral supracondylar ridge of the humerus, and from the lateral intermuscular septum. Interposed between it and the *Brachialis* are the radial nerve and the anastomosis between the *arteria profunda brachii* and the radial recurrent artery. The fibres end above the middle of the forearm in a flat tendon which is inserted into the lateral side of the base of the styloid process of the radius. The tendon is crossed near its insertion by the tendons of the *Abductor pollicis longus* and *Extensor pollicis brevis*; on its ulnar side is the radial artery.

The ***Extensor carpi radialis longus*** is partly covered by the *Brachioradialis*. It arises mainly from the lower third of the lateral supracondylar ridge of the humerus and from the lateral intermuscular septum, but it receives a few fibres from the common tendon of origin of the *Extensor* muscles of the forearm. The muscle ends at the upper third of the forearm in a flat tendon, which runs along the lateral border of the radius, deep to the *Abductor pollicis longus* and *Extensor pollicis brevis*; it then passes under cover of the dorsal carpal ligament, where it lies in a groove on the back of the radius common to it and the *Extensor carpi radialis brevis*, immediately behind the styloid process. It is inserted into the dorsal surface of the base of the second metacarpal bone, on its radial side.

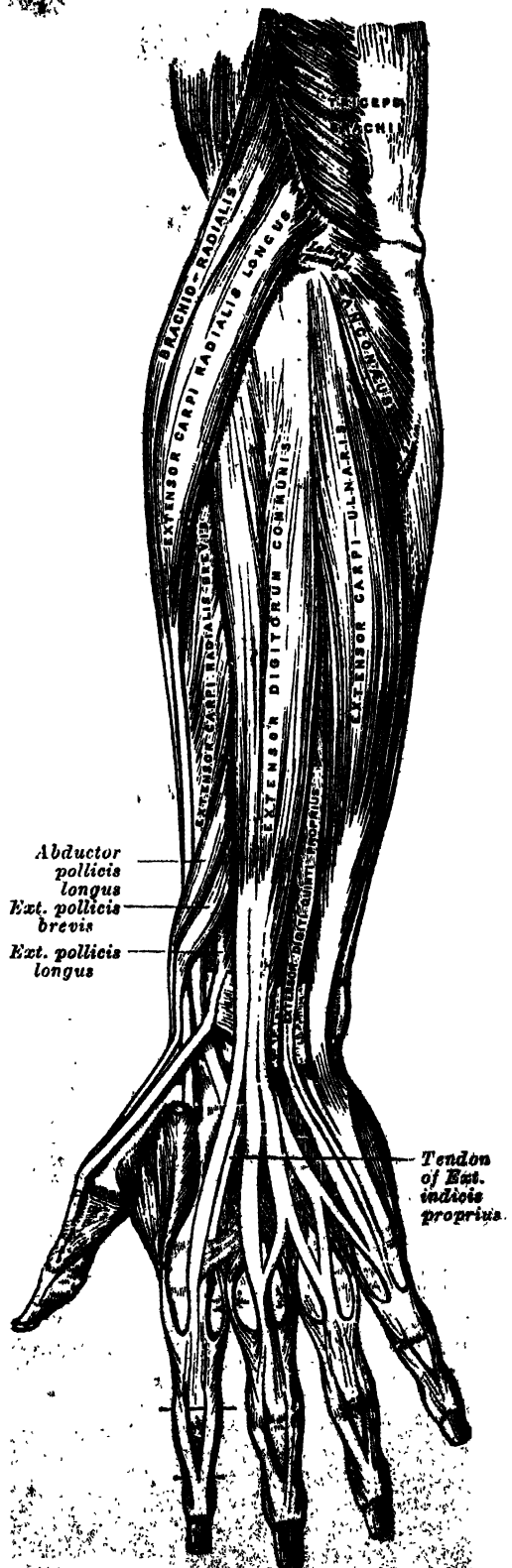
The ***Extensor carpi radialis brevis*** is shorter than the preceding muscle and is covered by it. It arises from the lateral epicondyle of the humerus, by a tendon common to it and the next three muscles; from the radial collateral ligament of the elbow-joint; from a strong aponeurosis which covers its surface; and from the intermuscular septa between it and the adjacent muscles. The fibres end about the middle of the forearm in a flat tendon, which closely accompanies that of the preceding muscle to the wrist; it passes beneath the *Abductor pollicis longus* and *Extensor pollicis brevis*, then under cover of the dorsal carpal ligament, and is inserted into the dorsal surface of the base of the third metacarpal bone on its radial side and distal to the styloid process. Under the dorsal carpal ligament the tendon lies on the back of the radius in a shallow groove, to the ulnar side of the groove which lodges the tendon of the *Extensor carpi radialis longus*, and separated from it by a faint ridge.

The tendons of the two preceding muscles pass through the same compartment of the dorsal carpal ligament in a single mucous sheath.

The *Extensor digitorum communis* arises from the lateral epicondyle of the humerus, by the common tendon; from the intermuscular septa between it and the adjacent muscles, and from the antibrachial fascia. It divides below into four tendons, which pass, together with that of the *Extensor indicis proprius*, through a compartment of the dorsal carpal ligament, within a mucous sheath. The tendons then diverge on the back of the hand, and are inserted into the second and third phalanges of the fingers in the following manner. Opposite the metacarpophalangeal articulation each tendon is bound by fasciculi to the collateral ligaments and serves as the dorsal ligament of this joint; after crossing the joint, it spreads out into a broad aponeurosis, which covers the dorsal surface of the first phalanx and is there reinforced by the corresponding tendons of the *Interossei* and *Lumbricalis*. Opposite the first interphalangeal joint this aponeurosis divides into three slips, an intermediate and two collateral: the intermediate is inserted into the base of the second phalanx; the two collateral are continued onwards along the sides of the second phalanx, and uniting by their contiguous margins, are inserted into the dorsal surface of the unguis phalanx. As the tendons cross the interphalangeal joints, they furnish them with dorsal ligaments. The tendon to the index finger is accompanied by the *Extensor indicis proprius*, which lies on its ulnar side. On the back of the hand, the tendons to the middle, ring, and little fingers are connected by two obliquely placed bands, one from the third tendon passing distalwards and lateralwards to the second tendon, and the other passing from the fourth tendon to the third. Occasionally the second tendon is connected to the first by a thin oblique band.

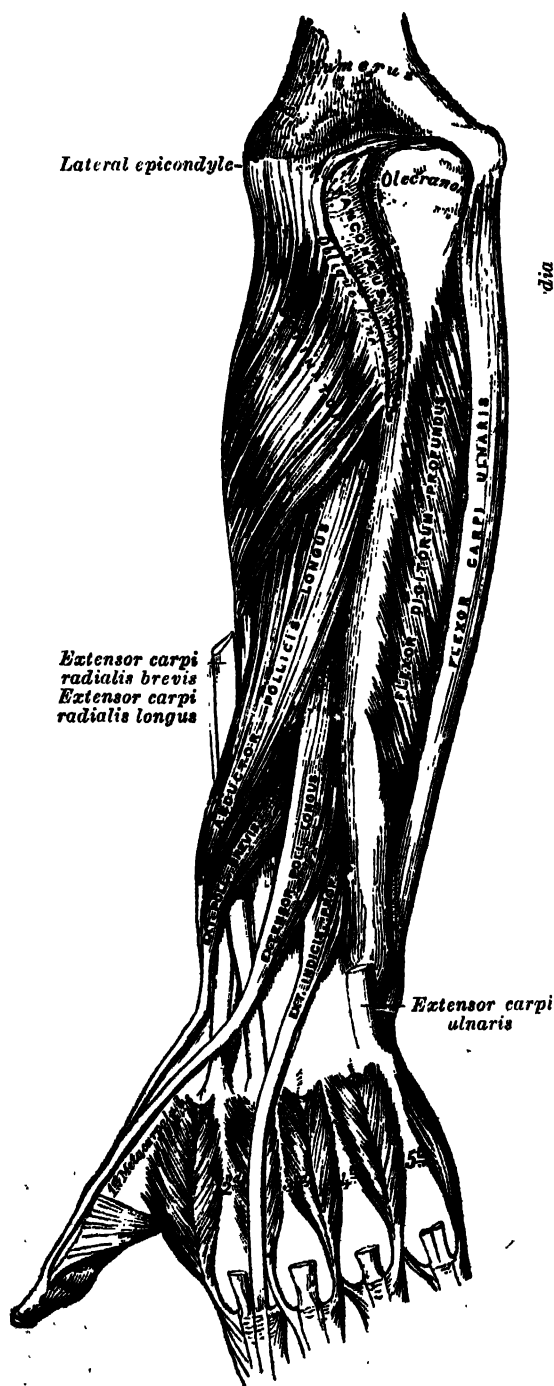
The *Extensor digiti quinti proprius* is a slender muscle placed medially to, and usually connected with, the *Extensor digitorum communis*. It arises

Fig. 554.—Posterior surface of the forearm. Superficial muscles.



from the common Extensor tendon by a thin tendinous slip, and from the inter-muscular septa between it and the adjacent muscles. Its tendon runs through

FIG. 555.—Posterior surface of the forearm.
Deep muscles.



a compartment of the dorsal carpal ligament behind the distal radio-ulnar joint, then divides into two as it crosses the hand, and finally joins the expansion of the Extensor digitorum communis tendon on the dorsum of the first phalanx of the fifth digit.

The **Extensor carpi ulnaris** lies on the ulnar side of the forearm. It arises from the lateral epicondyle of the humerus, by the common extensor tendon; from the dorsal border of the ulna by an aponeurosis in common with the **Flexor carpi ulnaris** and the **Flexor digitorum profundus**; and from the antibrachial fascia. It ends in a tendon, which runs in a groove between the head and the styloid process of the ulna, passing through a separate compartment of the dorsal carpal ligament, and is inserted into the tubercle on the ulnar side of the base of the fifth metacarpal bone.

The **Anconæus** is a small triangular muscle on the back of the elbow-joint, and appears to be a continuation of the **Triceps brachii**. It arises by a separate tendon from the posterior part of the lateral epicondyle of the humerus; its fibres diverge and are inserted into the side of the olecranon, and upper fourth of the dorsal surface of the body of the ulna.

(b) *Deep Group* (fig. 555)

Supinator.

Abductor pollicis longus.

Extensor pollicis brevis.

Extensor pollicis longus.

Extensor indicis proprius.

The **Supinator** (**Supinator brevis**) (fig. 556) curves round the upper third of the radius. It consists of fibres arranged in two planes, between which the deep branch of the radial nerve passes. The two planes arise in common—the superficial one by tendinous and the deeper by muscular fibres—from the lateral epicondyle of the humerus; from the radial collateral ligament of the elbow-joint, and the annular ligament of the proximal radio-ulnar

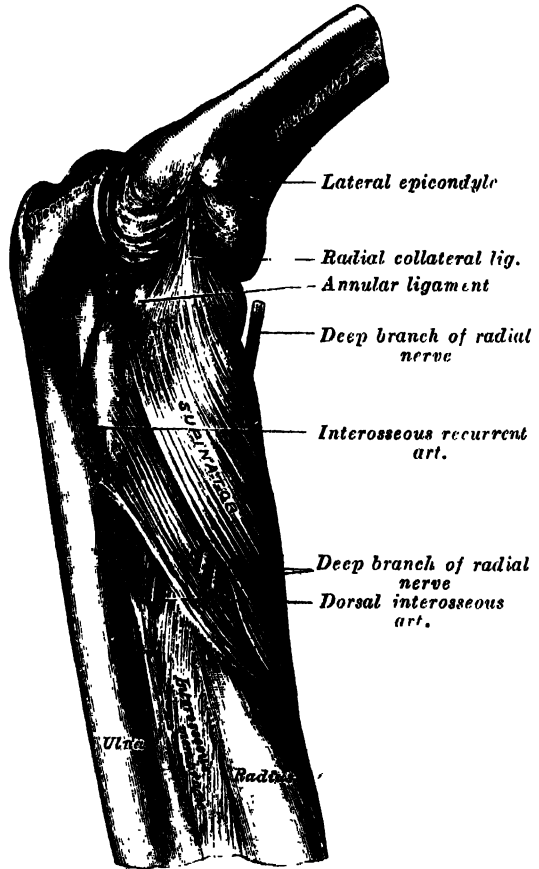
joint; from the ridge on the ulna, which runs obliquely downwards from the dorsal end of the radial notch; from the distal part of the triangular depression below the notch; and from a tendinous expansion which covers the surface of the muscle. The superficial fibres surround the upper part of the radius, and are inserted into the lateral edge of the radial tuberosity and the oblique line of the radius as low down as the insertion of the Pronator teres. The upper fibres of the deeper plane form a sling-like fasciculus, which encircles the neck of the radius above the tuberosity and is attached to the back part of its medial surface: the greater part of this portion of the muscle is inserted into the dorsal and lateral surfaces of the body of the radius, between the oblique line and the head of the bone.

FIG. 558.—The Supinator.

The **Abductor pollicis longus** (*Extensor ossis metacarpi pollicis*) lies immediately below the Supinator and is sometimes united with it. It arises from the lateral part of the dorsal surface of the body of the ulna below the insertion of the Anconæus, from the interosseous membrane, and from the middle third of the dorsal surface of the body of the radius. Passing obliquely downwards and lateralwards, it ends in a tendon, which runs through a groove on the lateral side of the lower end of the radius, accompanied by the tendon of the *Extensor pollicis brevis*, and is inserted into the radial side of the base of the first metacarpal bone. It occasionally gives off two slips near its insertion: one to the greater multangular bone, and the other to blend with the origin of the *Abductor pollicis brevis*.

The **Extensor pollicis brevis** lies on the medial side of, and is closely connected with, the *Abductor pollicis longus*. It arises from the dorsal surface of the body of the radius below that muscle, and from the interosseous membrane. Its direction is similar to that of the *Abductor pollicis longus*, its tendon passing through the same groove on the lateral side of the lower end of the radius, to be inserted into the dorsal aspect of the base of the first phalanx of the thumb.

The **Extensor pollicis longus** is larger than the preceding muscle, the origin of which it partly covers. It arises from the lateral part of the middle third of the dorsal surface of the body of the ulna below the origin of the *Abductor pollicis longus*, and from the interosseous membrane. It ends in a tendon, which passes through a compartment of the dorsal carpal ligament, lying in a narrow, oblique groove on the back of the lower end of the radius. It then crosses obliquely the tendons of the *Extensores carpi radialis longus* and *brevis*, and is separated from the *Extensor brevis pollicis* by a triangular interval, in which the radial artery is found; it is inserted into the base of the last phalanx of the thumb. The radial artery is crossed by the tendons of the *Abductor pollicis longus* and of the *Extensores pollicis longus* and *brevis*.



The *Extensor indicis proprius* is a narrow, elongated muscle, placed medially to, and parallel with, the preceding. It arises from the dorsal surface of the body of the ulna below the origin of the *Extensor pollicis longus*, and from the interosseous membrane. Its tendon passes under cover of the dorsal carpal ligament in the same compartment as that which transmits the tendons of the *Extensor digitorum communis*; opposite the head of the second metacarpal bone it joins the ulnar side of the tendon of the *Extensor digitorum communis* which runs to the index finger.

Nerves.—The *Brachioradialis* is supplied by the fifth and sixth, the *Extensores carpi radialis longus* and *brevis* by the sixth and seventh, and the *Anconæus* by the seventh and eighth cervical nerves, through the radial nerve; the remaining muscles are innervated through the deep radial nerve, the *Supinator* being supplied by the sixth, and the others by the seventh cervical.

Actions.—The *Anconæus* assists the *Triceps* in extending the forearm. The *Brachioradialis* is a flexor of the elbow-joint, but only acts as such when the movement of flexion has been initiated by the *Biceps brachii* and *Brachialis*. The *Supinator* and *Biceps brachii* bring the hand into the supine position. The *Extensor carpi radialis longus* extends the wrist and abducts the hand, and may assist in bending the elbow-joint; at all events it serves to fix or steady this articulation. The *Extensor carpi radialis brevis* extends the wrist, and may also act slightly as an abductor of the hand. The *Extensor carpi ulnaris* extends the wrist, but when acting alone inclines the hand towards the ulnar side: by its continued action it extends the elbow-joint. The *Extensor digitorum communis* extends the phalanges, then the wrist, and finally the elbow. Owing to its attachments to the collateral ligaments of the metacarpophalangeal joints it acts principally on the proximal phalanges, the middle and terminal phalanges being extended mainly by the *Interossei* and *Lumbricales*; it tends to separate the fingers as it extends them. The *Extensor digiti quinti proprius* extends the little finger, and by its continued action assists in extending the wrist; it is owing to this muscle that the little finger can be extended or pointed while the others are flexed. The chief action of the *Abductor pollicis longus* is to carry the thumb lateralwards from the palm of the hand; by its continued action it helps to extend and abduct the wrist. The *Extensor pollicis brevis* extends the proximal phalanx, and the *Extensor pollicis longus* the terminal phalanx of the thumb; they help to extend and abduct the wrist. The *Extensor indicis proprius* extends the index finger, and assists in extending the wrist.

Applied Anatomy.—The tendons of the *Abductor longus* and *Extensors* of the thumb are liable to become strained, and their sheaths inflamed (*tenosynovitis*) after excessive exercise, producing a sausage-shaped swelling along the course of the tendons and giving a peculiar grating sensation to the touch when the muscles are put in action.

Paralysis of the extensor muscles of the wrists and fingers resulting in 'wrist-drop' is common in lead poisoning in painters. The *Brachioradialis* usually escapes, unless the muscles of the upper arm are paralysed also. The different extensor muscles are affected unequally as a rule. Thus the thumb, or index, or little finger may be but slightly implicated, and recover rapidly while the extensors of the other fingers or wrist remain powerless; and some of the flexor muscles of the fingers may become paretic. This apparently selective action of the lead in cases of lead poisoning depends in reality upon occupational overuse of the affected muscles or groups of muscles. Muscular atrophy often follows this lead palsy.

VI. MUSCLES OF THE HAND

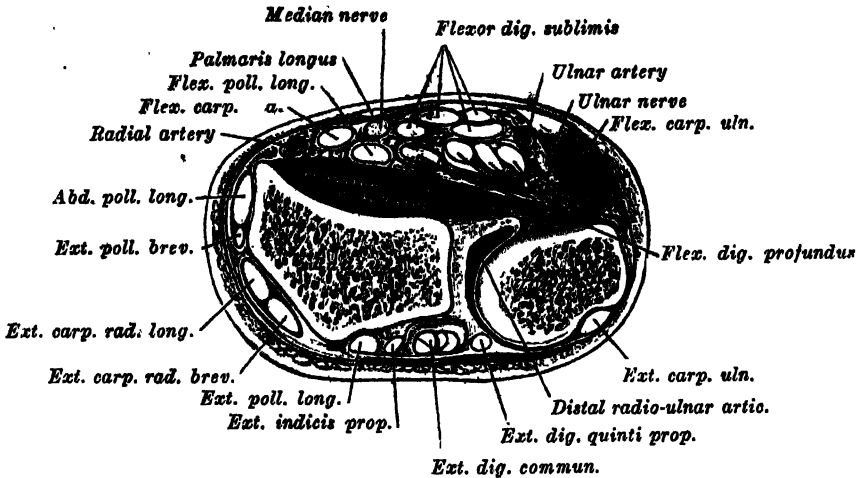
The muscles of the hand are subdivided into three groups: 1, those of the thumb, which occupy the radial side and produce the *thenar* eminence; 2, those of the little finger, which occupy the ulnar side and give rise to the *hypothenar* eminence; 3, those in the middle of the palm and between the metacarpal bones.

The volar carpal ligament is the thickened band of antibrachial fascia which extends from the radius to the ulna in front of the *Flexor* tendons as they approach the wrist.

The transverse carpal ligament (anterior annular ligament) (fig. 558, 559) is a strong, fibrous band, which arches over the front of the carpus, converting the deep groove on the front of the carpal bones into a tunnel, through which

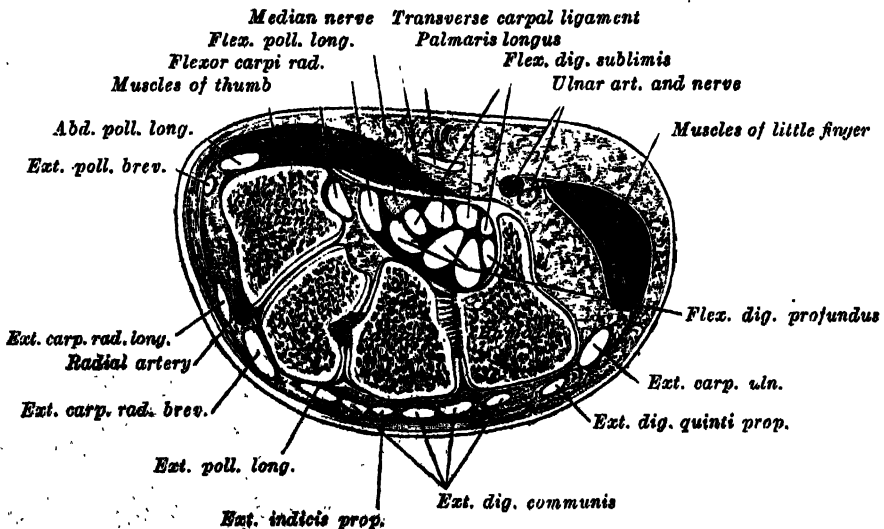
the flexor tendons of the digits and the median nerve pass. It is attached, medially, to the pisiform bone and to the hamulus of the hamate bone; laterally, it splits into two laminae, a superficial attached to the tubercles of the navicular and greater multangular bones, and a deep to the posterior lip of the groove

FIG. 557.—Transverse section across distal ends of radius and ulna.



on the latter bone; the two laminae forming with the groove on the greater multangular bone a tunnel which is traversed by the tendon of the Flexor carpi radialis, contained in a special mucous sheath. It is continuous, above, with the volar carpal ligament; and below, with the palmar aponeurosis. It is crossed superficially by the ulnar vessels and nerve, and the cutaneous

FIG. 558.—Transverse section across the wrist.

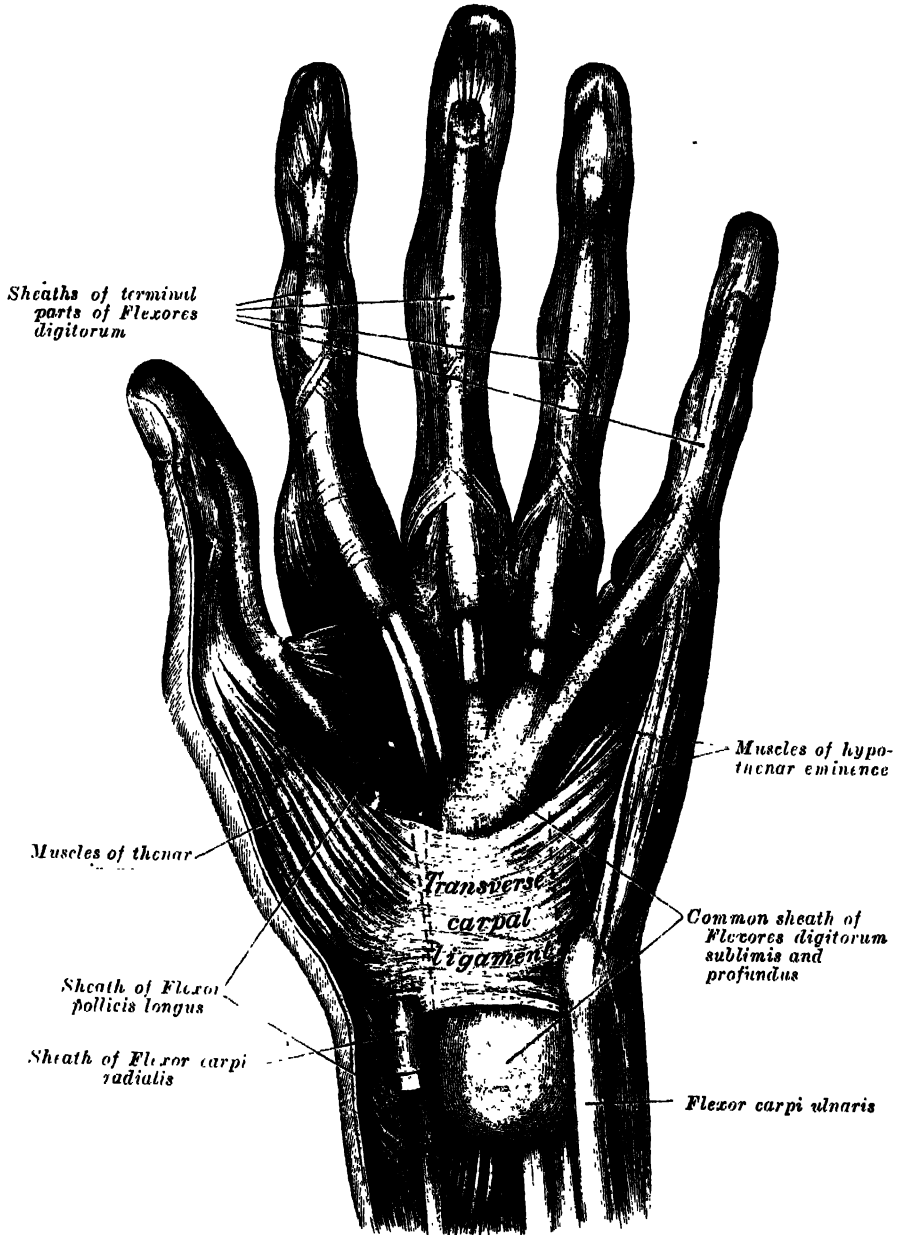


branches of the median and ulnar nerves. On its volar surface the tendons of the Palmaris longus and Flexor carpi ulnaris are partly inserted; below, it gives origin to the short muscles of the thumb and little finger.

The mucous sheaths of the tendons on the front of the wrist.—Two sheaths envelop the tendons as they pass behind the transverse carpal ligament, one for the Flexores digitorum sublimis and profundus, the other for the Flexor

pollicis longus (fig. 559). They extend into the forearm for about 2.5 cm. above the transverse carpal ligament, and occasionally communicate with each other behind the ligament. The sheath surrounding the Flexores digitorum reaches about halfway along the metacarpal bones, where it ends in blind diverticula

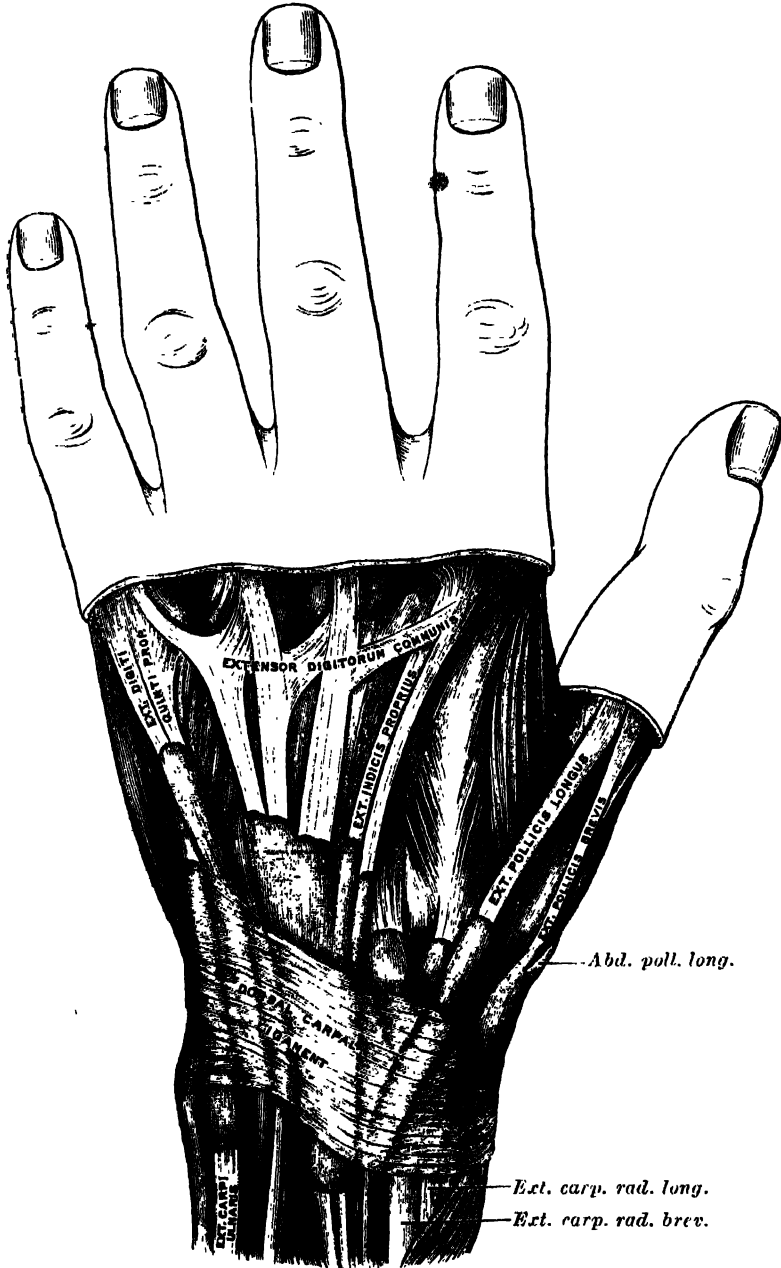
FIG. 559.—The mucous sheaths of the tendons on the front of the wrist and digits.



around the tendons to the index, middle, and ring fingers. It is prolonged on the tendons to the little finger and usually communicates with the digital mucous sheath of these tendons. The sheath of the tendon of the Flexor pollicis longus is continued along the thumb as far as the insertion of the tendon. The mucous sheaths enveloping the terminal parts of the tendons of the Flexores digitorum have been described on pp. 493, 494.

The dorsal carpal ligament (posterior annular ligament) (fig. 560) is a strong, fibrous band, extending obliquely downwards and medialwards across the back of the wrist, and consisting of part of the antibrachial fascia, strengthened by the addition of some transverse fibres. It is attached, medially,

FIG. 560.—The mucous sheaths of the tendons on the back of the wrist.

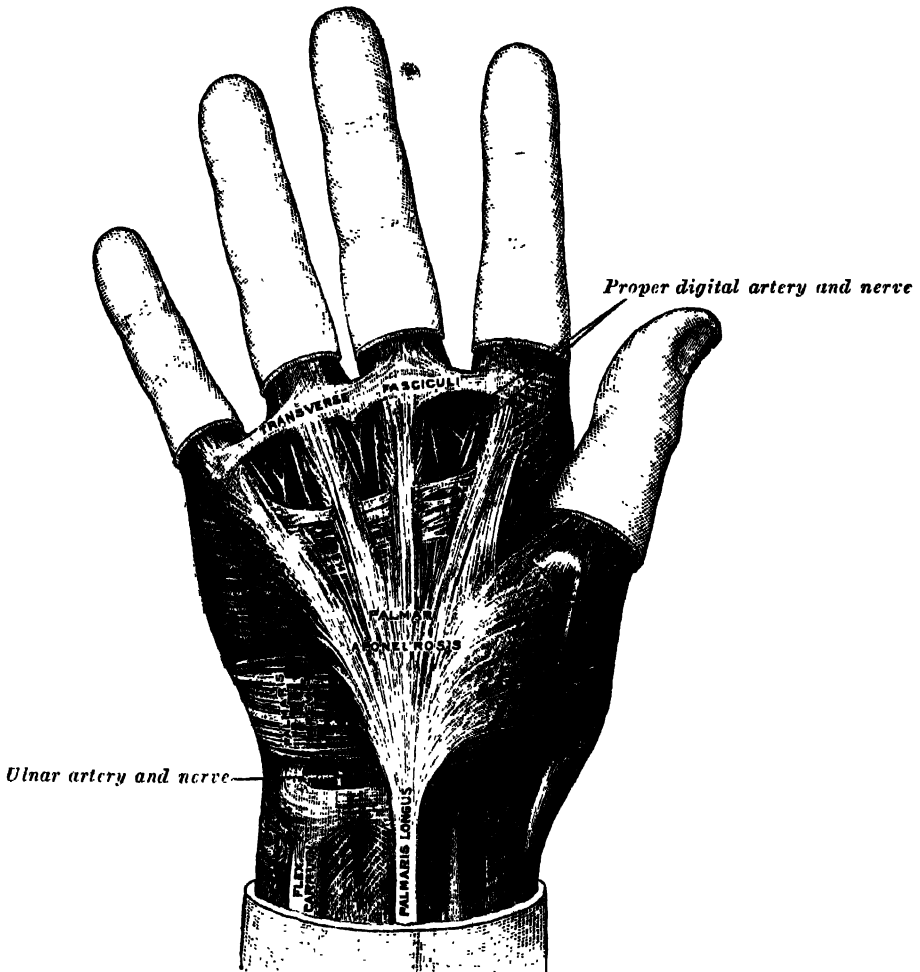


to the styloid process of the ulna and to the triquetral and pisiform bones; laterally, to the lateral margin of the radius; and, in its passage across the wrist, to the ridges on the dorsal surface of the radius.

The mucous sheaths of the tendons on the back of the wrist.—Between the dorsal carpal ligament and the bones six compartments are formed for the passage of tendons, each compartment containing a mucous sheath.

One is found in each of the following positions (fig. 560) : (1) on the lateral side of the styloid process, for the tendons of the Abductor pollicis longus and Extensor pollicis brevis ; (2) behind the styloid process, for the tendons of the Extensores carpi radialis longus and brevis ; (3) about the middle of the dorsal surface of the radius, for the tendon of the Extensor pollicis longus ; (4) to the medial side of the latter, for the tendons of the Extensor digitorum communis and Extensor indicis proprius ; (5) opposite the interval between the radius and ulna, for the Extensor digiti quinti proprius ; (6) between the head and styloid processes of the ulna, for the tendon of the Extensor carpi ulnaris.

FIG. 561.—The palmar aponeurosis.



The sheaths lining these compartments extend from above the dorsal carpal ligament ; those for the tendons of Abductor pollicis longus, Extensor pollicis brevis, Extensores carpi radiales, and Extensor carpi ulnaris stop immediately proximal to the bases of the metacarpal bones, while the sheaths for Extensor digitorum communis, Extensor indicis proprius, and Extensor digiti quinti proprius are prolonged to the junction of the proximal with the intermediate third of the metacarpus.

The **palmar aponeurosis** (fig. 561) invests the muscles of the palm, and consists of central, lateral, and medial portions.

The *central portion* occupies the middle of the palm, is triangular in shape, and of great strength and thickness. Its apex is continuous with the lower margin of the transverse carpal ligament, and gives insertion to the expanded tendon of the Palmaris longus. Its base divides below into four slips, one for

each finger. Each slip gives off superficial fibres to the skin of the palm and finger, those to the palm joining the skin at the furrow corresponding to the metacarpophalangeal articulations, and those to the fingers passing into the skin at the transverse folds at the bases of the fingers. The deeper part of each slip subdivides into two processes, which are inserted into the fibrous sheaths of the flexor tendons; from the sides of these processes offsets are attached to the transverse metacarpal ligament. By this arrangement short channels are formed on the front of the heads of the metacarpal bones; through these the flexor tendons pass. The intervals between the four slips transmit the digital vessels and nerves, and the tendons of the Lumbricales. At the points of division into the slips mentioned, numerous strong, transverse fibres bind the separate processes together. The central part of the palmar aponeurosis is intimately bound to the skin by dense fibro-areolar tissue, and gives origin by its medial margin to the *Palmaris brevis*. It covers the superficial volar arch, the tendons of the Flexor digitorum muscles, the terminal part of the median nerve, and the superficial part of the ulnar nerve; on either side it gives off a septum which separates the intermediate from the lateral and medial groups of muscles.

The *lateral and medial portions* of the palmar aponeurosis are thin, fibrous layers, which cover the muscles of the ball of the thumb, and the muscles of the little finger respectively; they are continuous with the central portion and with the fascia on the dorsum of the hand.

The *superficial transverse fasciculi* form a thin band (fig. 561) which stretches across the roots of the fingers, and is attached to the skin of the clefts, and medially to the fifth metacarpal bone, forming a sort of rudimentary web. The digital vessels and nerves pass beneath these fasciculi.

Applied Anatomy.—The palmar aponeurosis is liable to undergo contraction, producing a very inconvenient deformity, known as ‘Dupuytren’s contraction.’ The ring and little fingers are most frequently implicated, but the others may also be involved. The proximal phalanx is flexed and cannot be straightened, and the two distal phalanges become similarly flexed as the disease advances.

Owing to their constant exposure to injury and septic influences, the fingers are very liable to become the seat of serious inflammatory mischief. To this inflammation the term *paronychia* or *whitlow* is given, and the affection may assume various degrees of severity. In the mildest cases the disease is confined to the superficial layer of the skin, and suppuration takes place beneath it. This is known as *subcuticular paronychia*, and is a comparatively simple condition, for an incision through the epidermis will at once relieve it. The only complication is that the pus may burrow under the nail, causing increased pain. A more severe condition is the *paronychia cellulosa*, in which the pulp of the end of the finger is involved. This is attended with intense throbbing pain, owing to the fact that the inflamed area is covered by thick and often horny epithelium, especially when the disease occurs in the labouring classes, as it so frequently does. In these cases, unless a timely incision is made, the inflammation is liable to involve the periosteum covering the phalanx, and *subperiosteal paronychia* is set up, which is followed by necrosis of a part or the whole of the ungual phalanx. In other cases, the inflammation may involve the theca of the flexor tendons, and a *thecal paronychia* may result. The inflammation then rapidly spreads up the sheath: but the extent will depend upon the particular digit involved. From the description of the flexor sheaths given above, it will be evident that inflammation of the mucous sheaths of the thumb and little finger may prove a far more formidable affection than that of the other three digits, because the sheaths of these two digits communicate with the large mucous sheath which surrounds the flexor tendons (pp. 501, 502), and the inflammation may extend into the palm of the hand and behind the transverse carpal ligament into the forearm.

In order to relieve these conditions, free and early incisions are necessary, and must be made with discrimination, in order to avoid wounding important structures. In the pulp of the finger—i.e. over the distal phalanx—the incision should be made in the middle line and down to the bone. In the rest of the finger, the incision should be made in the middle line over the phalanges, and not over the interphalangeal joints. In the palm of the hand, incisions may be made either on the distal or proximal side of the superficial volar arch. On the distal side the incisions should be made over the metacarpal bones, preferably those of the index and middle finger. On the proximal side, the safest line of incision is along the radial side of the hypothenar eminence, between the ulnar artery and nerve medially, and the median nerve laterally. When suppuration has extended under the transverse carpal ligament, and incisions are required in the forearm, the positions in which they should be made are over the tendons of the Flexor digitorum sublimis, between the median nerve and the ulnar artery, and over the tendon of the Flexor pollicis longus, between the radial artery and the tendon of the Flexor carpi radialis.

Chronic inflammation of the common flexor sheath is occasionally met with, constituting a disease known as *compound palmar ganglion*; it presents an hour-glass outline, with a swelling in front of the wrist and another in the palm of the hand, and a constriction, corresponding to the transverse carpal ligament, between the two. The fluid can be forced from the one swelling to the other under the ligament, and when this is done, a creaking sensation is sometimes perceived, from the presence of 'melon-seed' bodies in the interior of the ganglion.

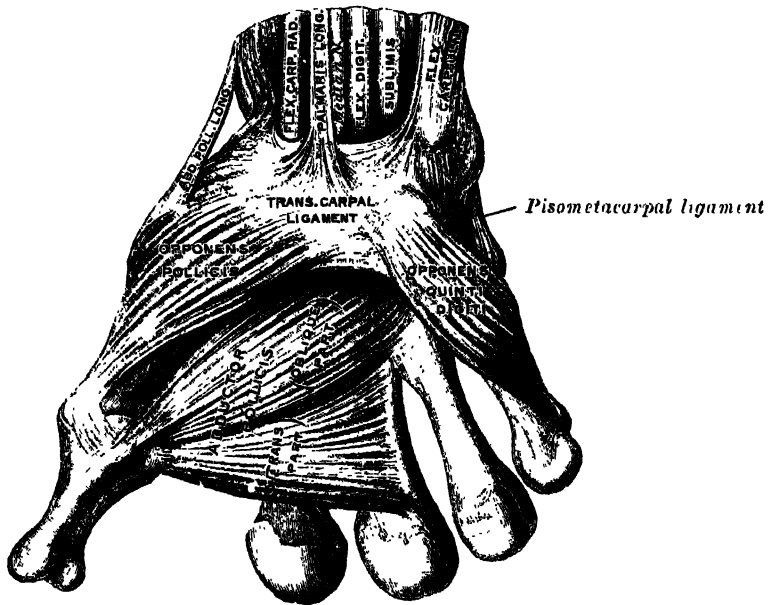
1. LATERAL VOLAR MUSCLES (figs. 562, 563)

Abductor pollicis brevis.
Opponens pollicis.

Flexor pollicis brevis.
Adductor pollicis.

The **Abductor pollicis brevis** is a thin, subcutaneous muscle; it arises from the transverse carpal ligament, the tuberosity of the navicular bone, and the ridge of the greater multangular bone. Running lateralwards and downwards, it is inserted by a thin, flat tendon into the radial side of the base of the

FIG. 562.—The Opponens pollicis, Adductor pollicis and Opponens digiti quinti muscles.



first phalanx of the thumb and the capsule of the metacarpophalangeal articulation.

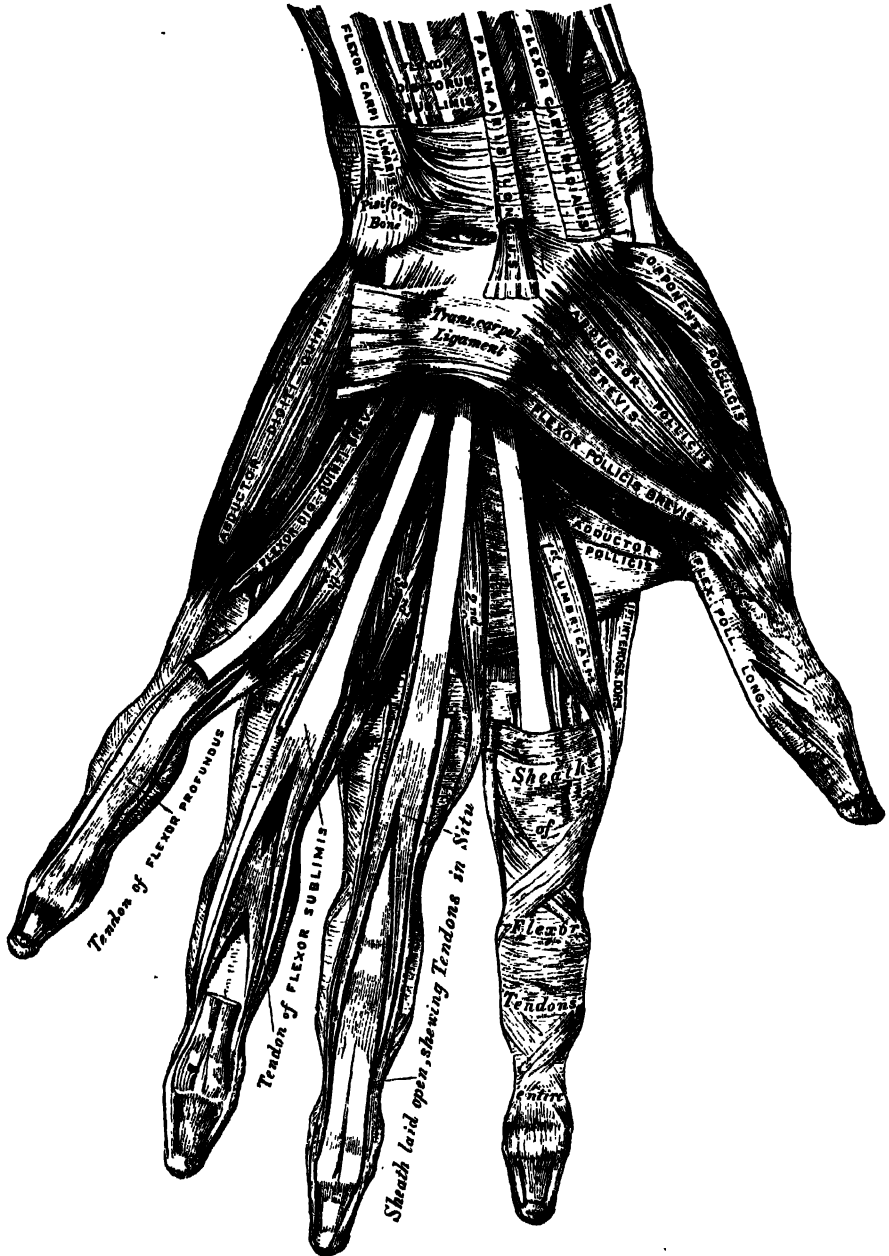
The **Opponens pollicis** is placed beneath the preceding. It arises from the ridge on the greater multangular bone, and from the transverse carpal ligament, passes downwards and lateralwards, and is inserted into the whole length of the metacarpal bone of the thumb on its radial side.

The **Flexor pollicis brevis** consists of two portions, superficial and deep. The *superficial portion* arises from the lower border of the transverse carpal ligament and the lower part of the ridge on the greater multangular bone; it passes along the radial side of the tendon of the Flexor pollicis longus, and is inserted into the radial side of the base of the first phalanx of the thumb; in its tendon of insertion there is a sesamoid bone. The *deep portion* is very small. It arises from the ulnar side of the base of the first metacarpal bone and is inserted into the ulnar side of the base of the first phalanx with the oblique part of the Adductor pollicis; it is sometimes described as the *first volar interosseous muscle*.

The **Adductor pollicis** consists of an oblique and a transverse part. The *oblique part* arises from the capitate and lesser multangular bones, the bases

of the second and third metacarpal bones, the intercarpal ligaments, and the sheath of the tendon of the Flexor carpi radialis. Most of its fibres converge to a tendon, which, uniting with the tendons of the deep portion of the Flexor pollicis brevis and the transverse part of the Adductor, is inserted into the

FIG. 563.—The muscles of the left hand. Palmar surface.



ulnar side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon. A considerable fasciculus, however, passes beneath the tendon of the Flexor pollicis longus and joins the superficial portion of the Flexor brevis and the Abductor pollicis brevis. The *transverse part* (fig. 562) is the most deeply seated of this group of muscles. It is of a triangular form, and arises from the distal two-thirds of the volar surface of the third metacarpal

bone ; the fibres converge, to be inserted with the oblique part of the muscle and with the deep part of the *Flexor pollicis brevis* into the ulnar side of the base of the first phalanx of the thumb.

Nerves.—The *Abductor pollicis brevis*, *Opponens pollicis*, and superficial portion of the *Flexor pollicis brevis* are supplied by the sixth and seventh cervical nerves through the median nerve ; the *Adductor* and the deep portion of the *Flexor pollicis brevis*, by the eighth cervical nerve through the ulnar nerve.

Actions.—The *Abductor pollicis brevis* draws the thumb forwards in a plane at right angles to that of the palm of the hand and abducts the proximal phalanx. The *Adductor pollicis* is the opponent of this muscle, and approximates the thumb to the palm. The *Opponens pollicis* flexes the metacarpal bone, i.e. draws it medialwards over the palm ; the *Flexor pollicis brevis* flexes and adducts the proximal phalanx.

2. MEDIAL VOLAR MUSCLES (figs. 562, 563)

Palmaris brevis.
Abductor digiti quinti.

Flexor digiti quinti brevis.
Opponens digiti quinti.

The *Palmaris brevis* is a thin, quadrilateral muscle, placed beneath the skin of the ulnar side of the hand. It arises by tendinous fasciculi from the transverse carpal ligament and palmar aponeurosis ; the fleshy fibres are inserted into the skin on the proximal part of the ulnar border of the hand.

The *Abductor digiti quinti* is situated on the ulnar border of the palm of the hand. It arises from the pisiform bone and from the tendon of the *Flexor carpi ulnaris*, and ends in a flat tendon which divides into two slips ; one is inserted into the ulnar side of the base of the first phalanx of the little finger, the other into the ulnar border of the aponeurosis of the *Extensor digiti quinti proprius*.

The *Flexor digiti quinti brevis* lies on the radial side of the preceding muscle. It arises from the convex surface of the hamulus of the hamate bone and the volar surface of the transverse carpal ligament, and is inserted into the ulnar side of the base of the first phalanx of the little finger. It is separated from the *Abductor* by the deep branches of the ulnar artery and nerve. This muscle is sometimes wanting ; the *Abductor* is then, usually, of large size.

The *Opponens digiti quinti* (fig. 562) is of a triangular form, and placed under cover of the *Flexor* and *Abductor*. It arises from the convexity of the hamulus of the hamate bone, and contiguous portion of the transverse carpal ligament ; it is inserted into the whole length of the ulnar margin of the fifth metacarpal bone.

Nerves.—All the muscles of this group are supplied by the eighth cervical nerve through the ulnar nerve.

Actions.—The *Palmaris brevis* corrugates the skin on the ulnar side of the palm. The *Abductor* and *Flexor digiti quinti brevis* abduct the little finger and assist in flexing its proximal phalanx. The *Opponens digiti quinti* draws forwards the fifth metacarpal bone, so as to deepen the hollow of the palm.

3. INTERMEDIATE MUSCLES

Lumbricales.

Interossei.

The *Lumbricales* (fig. 563) are four small fleshy fasciculi, which take origin from the tendons of the *Flexor digitorum profundus*. The first and second arise from the radial sides and volar surfaces of the tendons of the index and middle fingers respectively ; the third, from the contiguous sides of the tendons of the middle and ring fingers ; and the fourth, from the contiguous sides of the tendons of the ring and little fingers. Each passes to the radial side of the corresponding finger, and opposite the metacarpophalangeal articulation is inserted into the tendinous expansion of the *Extensor digitorum communis* covering the dorsal aspect of the finger.

The *Interossei* (figs. 564, 565) occupy the intervals between the metacarpal bones, and are divided into a dorsal and a volar set.

The *Interossei dorsales*, four in number, are bipennate muscles, each arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the first phalanges and into the aponeuroses of the tendons of the *Extensor digitorum communis*. Between the double origin of each of these muscles is a narrow triangular interval; through the first of these intervals the radial artery passes; through each of the others a perforating branch from the deep volar arch is transmitted. The *first* or *Abductor indicis* is larger than the others; it is inserted into the radial side of the index finger. The *second* and *third* are inserted into the middle finger, the former into its radial, the latter into its ulnar side. The *fourth* is inserted into the ulnar side of the ring finger.

The *Interossei volares*, three in number, are smaller than the *Interossei dorsales*, and are placed upon the volar surfaces of the metacarpal bones, rather than between them. Each arises from the entire length of the metacarpal bone

FIG. 564.—The *Interossei dorsales* of left hand.

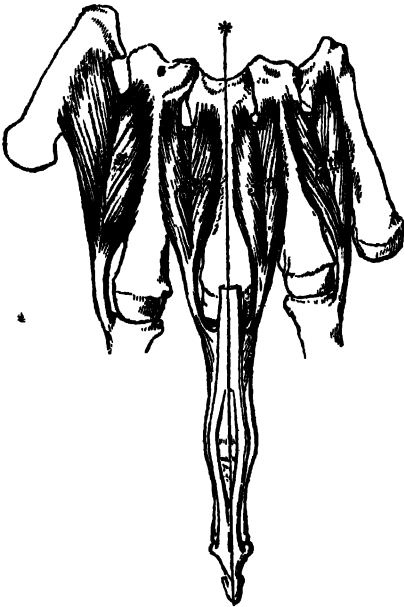
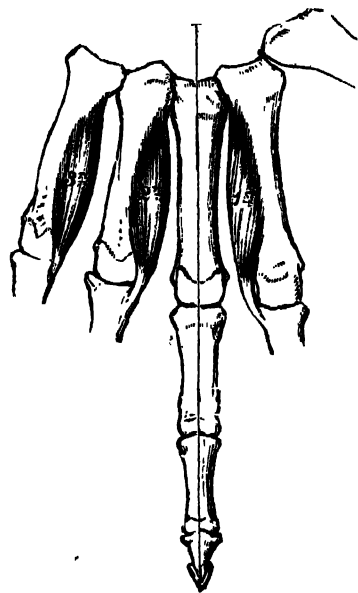


FIG. 565.—The *Interossei volares* of left hand.



of one finger, and is inserted into the side of the base of the first phalanx of the same finger, and into the aponeurotic expansion of the *Extensor communis digitorum* tendon.

The *first* arises from the ulnar side of the second metacarpal bone, and is inserted into the same side of the first phalanx of the index finger. The *second* arises from the radial side of the fourth metacarpal bone, and is inserted into the same side of the ring finger. The *third* arises from the radial side of the fifth metacarpal bone, and is inserted into the same side of the little finger. From this account it may be seen that each finger is provided with a pair of *Interossei*, with the exception of the little finger, in which the *Abductor* takes the place of one of the pair.

As already mentioned (p. 506), the deep head of *Flexor pollicis brevis* is sometimes described as the first volar interosseous muscle.

Nerves.—The first and second *Lumbricales* are supplied by the sixth and seventh cervical nerves through the third and fourth digital branches of the median nerve; the third and fourth *Lumbricales* and all the *Interossei* are supplied by the eighth cervical nerve, through the deep palmar branch of the ulnar nerve. The third *Lumbricalis* frequently receives a twig from the median nerve.

Actions.—The *Interossei volares* adduct the fingers to an imaginary line drawn longitudinally through the centre of the middle finger; and the *Interossei dorsales*

abduct the fingers from that line. The Interossei, in conjunction with the Lumbricales, flex the first phalanges, and, in consequence of their insertions into the expansions of the Extensor tendons, extend the second and third phalanges. The Extensor digitorum communis is believed to act almost entirely on the first phalanges.

Applied Anatomy.—In considering the actions of the various muscles upon fractures of the upper extremity, the most common forms of injury have been selected both for illustration and description.

Fracture of the middle of the clavicle (fig. 566) is usually attended with considerable displacement of the lateral fragment, which is drawn downwards and medialwards, and at the same time rotated, so that its lateral end is carried forwards and its medial end backwards.

The displacement is produced as follows: the lateral fragment is drawn downwards by the weight of the arm, the Trapezius not being able to support this. It is drawn medialwards by the Subclavius and Pectoralis minor, possibly assisted by the Pectoralis major

FIG. 566.—Fracture of the middle of the clavicle.

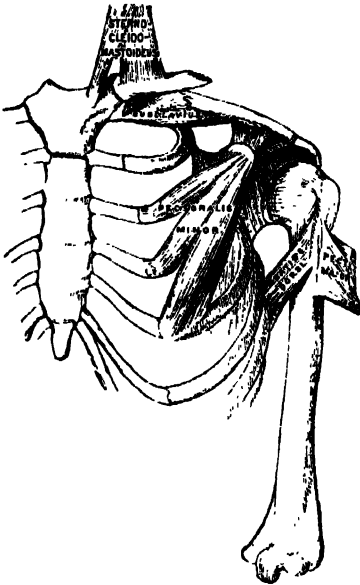
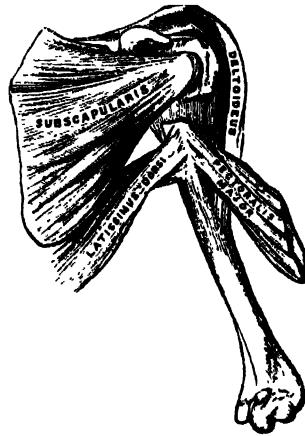


FIG. 567.—Fracture of the surgical neck of the humerus.



and Latissimus dorsi; and is rotated on an axis drawn through its own centre by the Serratus anterior, which causes the scapula to rotate on the wall of the chest, and carries the acromion and the end of the lateral fragment of the clavicle forwards, and so carries the medial end of the lateral portion backwards. The causes of displacement having been ascertained, it is easy to apply the appropriate treatment. The lateral fragment is to be drawn lateralwards, and, together with the scapula, raised to a level with the medial fragment, and retained in that position.

In fracture of the *acromial end of the clavicle*, between the conoid and trapezoid ligaments, only slight displacement occurs, as these ligaments, from their oblique insertion, serve to hold both portions of the bone in apposition. Fracture, also, of the *sternal end*, medial to the costoclavicular ligament, is attended with only slight displacement, this ligament serving to retain the fragments in close apposition.

Fracture of the *acromion* is usually caused by violence applied to the upper and lateral part of the shoulder. There is great displacement; the lateral fragment being drawn downwards by the weight of the arm, and rotated forwards and medialwards, so that it forms a right angle with the rest of the bone.

Fracture of the *surgical neck of the humerus* (fig. 567) is very common. It is attended with considerable displacement, and its appearances correspond somewhat with those of dislocation of the head of the humerus into the axilla. The upper fragment remains in its place under the coraco-acromial ligament; the lower is drawn medialwards by the Pectoralis major, Latissimus dorsi, and Teres major; and the humerus is thrown obliquely from the side of the chest by the Deltoides, and occasionally elevated so as to cause the upper end of the lower fragment to project beneath and in front of the coracoid process. The deformity is reduced by fixing the shoulder, and drawing the arm lateralwards and downwards. To counteract the opposing muscles, and to keep the fragments in position, a cone-shaped pad should be placed in the axilla, and the arm bandaged to the side by a broad roller passed round the chest in such a manner that the elbow is carried

slightly forwards, so as to throw the upper end of the lower fragment backwards and lateralwards towards the head of the bone. The whole is then covered with a carefully moulded guttapercha or poroplastic shoulder-cap.

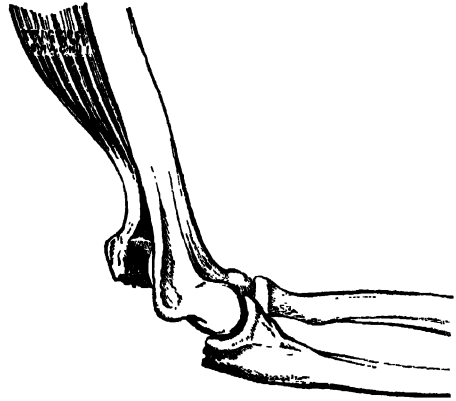
In fracture of the *body of the humerus* below the insertion of the Pectoralis major, Latissimus dorsi, and Teres major, and above the insertion of the Deltoideus, there is also considerable deformity, the upper fragment being drawn medialwards by the first-mentioned muscles, and the lower fragment upwards and lateralwards by the Deltoideus. Shortening of the limb results, with a considerable prominence at the seat of fracture, from the fractured ends of the bone riding over one another, especially if the fracture take place in an oblique direction. The fragments may be brought into apposition by extension from the elbow, and retained in that position by adopting the same means as in the preceding injury.

In fracture of the *body of the humerus* immediately below the insertion of the Deltoideus the amount of deformity depends greatly upon the direction of the fracture. If it occur in a transverse direction, only slight displacement takes place, the upper fragment being drawn a little forwards; but in oblique fracture, the combined actions of the Biceps brachii and Brachialis in front and the Triceps brachii behind draw upwards the lower fragment, causing it to glide over the upper, either backwards or forwards,

FIG. 568.—Fracture of the humerus above the condyles.



FIG. 569.—Fracture of the olecranon.



according to the direction of the fracture. Simple extension reduces the deformity, and the application of a shoulder-cap and splints to the arm will retain the fragments in apposition.

Fracture of the *humerus* immediately above the condyles (fig. 568) deserves very attentive consideration, as the general appearances correspond somewhat with those produced by separation of the epiphysis of the humerus, and with those of dislocation of the radius and ulna backwards. If the direction of the fracture is oblique, from above, downwards and forwards, the lower fragment is drawn upwards by the Brachialis and Biceps brachii in front, and the Triceps brachii behind; and at the same time is drawn backwards behind the upper fragment by the Triceps brachii. This fracture may be diagnosed from dislocation, by the increased mobility, the existence of crepitus, and the fact that the deformity is remedied by extension, but is reproduced on the discontinuance of it. The age of the patient is of importance in distinguishing this form of injury from separation of the epiphysis. In some cases where the injury has been produced by falls on the elbow, the lower fragment is drawn upwards and forwards, causing a considerable prominence in front, the upper fragment projecting backwards beneath the tendon of the Triceps brachii.

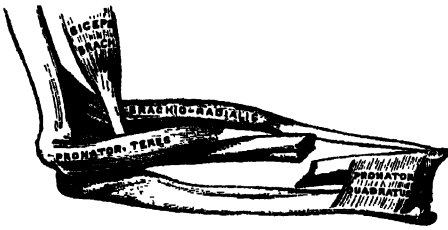
In fracture of the *olecranon* (fig. 569) the detached fragment is displaced upwards from 1 cm. to 5 cm. by the action of the Triceps brachii; the prominence of the elbow is consequently lost, and a deep hollow is felt at the back part of the joint, which is much increased on flexing the limb. The patient at the same time loses, more or less, the power of extending the forearm. The treatment consists in wiring the fragments together; but if for some reason this operation is not desirable, they should be approximated by strapping or a figure-of-8 bandage, and the arm put up in an extended position in order to relax the Triceps brachii. Massage and passive movements must be employed early, for fear of ankylosis. Union, when wiring is not resorted to, is usually fibrous.

In fracture of the *radius* below the insertion of the Biceps brachii, but above the insertion of the Pronator teres, the upper fragment is strongly supinated by the Biceps

brachii and Supinator, and at the same time drawn forwards by the Biceps brachii, the lower fragment is pronated and drawn towards the ulna by both Pronators. Thus there is extreme displacement with very little deformity. In treating such a fracture the arm must be put up in a position of supination, otherwise union will take place with great impairment of the movements of the hand. In fractures of the radius below the insertion of the Pronator teres (fig. 570), the upper fragment is drawn upwards by the Biceps brachii and medialwards by the Pronator teres, into a position midway between pronation and supination, and a degree of fulness in the upper half of the forearm is thus produced. The lower fragment is drawn downwards towards the ulna and pronated by the Pronator quadratus; at the same time, the Brachioradialis, by elevating the styloid process, into which it is inserted, will serve to depress the upper end of the lower fragment still more towards the ulna. In order to relax the opposing muscles the elbow should be flexed, and the limb placed in a position midway between pronation and supination; the fracture is then easily reduced by extension from the wrist and elbow. Well-padded splints should be applied on both sides of the forearm from the elbow to the wrist.

In fracture of the *body of the ulna* the upper fragment retains its usual position, but the lower is drawn towards the radius by the pronator quadratus, producing a well-marked depression at the seat of fracture, and some fulness on the dorsal and volar surfaces of the

FIG. 570.—Fracture of the body of the radius.

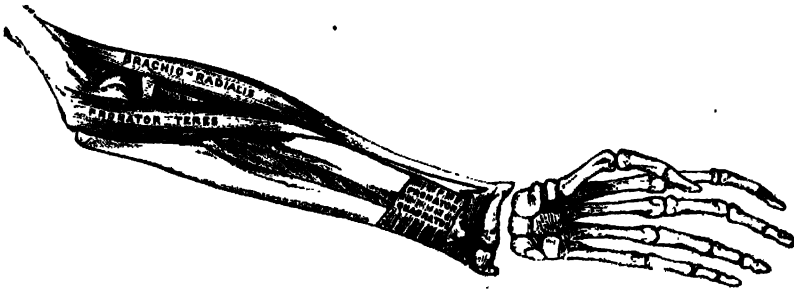


forearm. The fracture is easily reduced by extension from the wrist and elbow. The forearm should be flexed, and placed in a position midway between pronation and supination, and well-padded splints applied from the elbow to the ends of the fingers.

In fracture of the *bodies of the radius and ulna together*, the lower fragments are drawn upwards, sometimes forwards, sometimes backwards, according to the direction of the fracture, by the combined actions of the flexor and extensor muscles, producing a degree of fulness on either the dorsal or volar surface of the forearm. At the same time the lower fragments are drawn into contact by the Pronator quadratus, the radius being in a state of pronation. The upper fragment of the radius is drawn upwards and medialwards by the Biceps brachii and Pronator teres to a higher level than the ulna; the upper portion of the ulna is slightly elevated by the Brachialis. The fracture may be reduced by extension from the wrist and elbow, and the forearm should be placed in the same position as in fracture of the ulna.

In fracture of the *lower end of the radius* (fig. 571) the displacement produced is very considerable, and bears some resemblance to dislocation of the carpus backwards, from which it should be carefully distinguished. The lower fragment is displaced backwards

FIG. 571.—Fracture of the lower end of the radius.



and upwards, but this displacement is due to the force of the blow driving the portion of the bone into this position, and not to any muscular influence. The upper fragment projects forwards, often lacerating the substance of the Pronator quadratus, and is drawn by this muscle into close contact with the lower end of the ulna, causing a projection on the volar surface of the forearm, immediately above the carpus, from the Flexor tendons being thrust forwards. This fracture may be distinguished from dislocation by the relative positions of the styloid processes of the radius and ulna (the former of which is displaced upwards in fracture) and by the deformity being removed on making sufficient extension, when crepitus may be occasionally detected. The age of the patient will assist in determining whether the injury is fracture or separation of the epiphysis. The treatment consists in flexing the forearm, and making powerful extension from the wrist and elbow, depressing at the same time the radial side of the hand, and retaining the parts in a position of adduction towards the ulnar side.

FASCIÆ AND MUSCLES OF THE LOWER EXTREMITY

The muscles of the lower extremity are subdivided into groups corresponding with the different regions of the limb.

- I. Muscles of the iliac region.
- II. Muscles of the thigh.

- III. Muscles of the leg.
- IV. Muscles of the foot.

I. MUSCLES OF THE ILIAC REGION (fig. 572)

Psoas major.

Psoas minor.

Iliacus.

The **fascia iliaca** covers the Psoas and Iliacus. It is thin above, and becomes gradually thicker as it approaches the inguinal ligament.

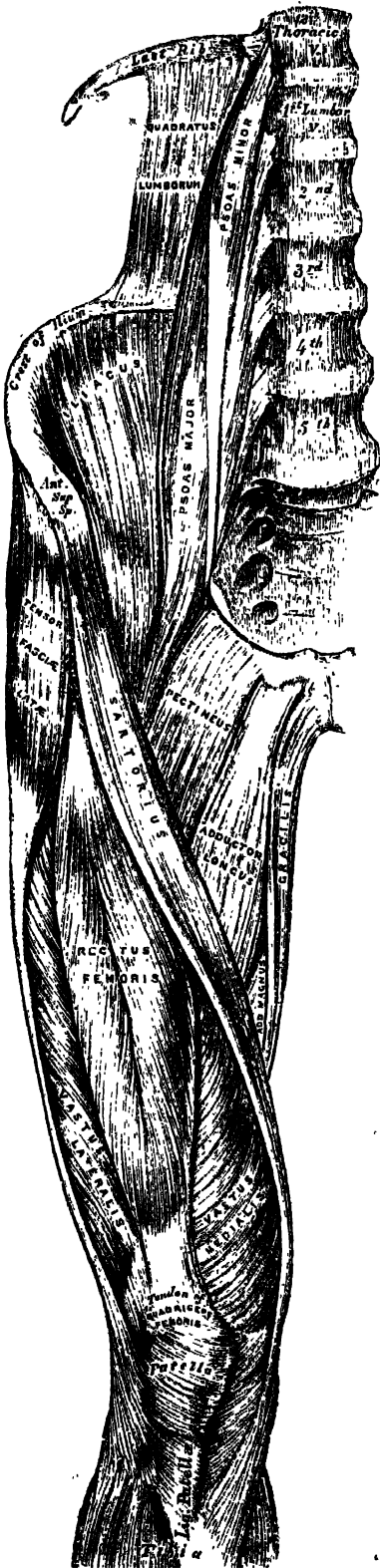
The *portion covering the Psoas* is thickened above to form the medial lumbo-costal arch, which stretches from the transverse process of the first to the body of the second lumbar vertebra. Medially, it is attached by a series of arched processes to the intervertebral fibrocartilages, and prominent margins of the bodies of the vertebræ, and to the upper part of the sacrum; the intervals opposite the constricted portions of the bodies transmit the lumbar arteries and veins and filaments of the sympathetic trunk. Laterally, above the crest of the ilium, it is continuous with the fascia covering the front of the Quadratus lumborum (see p. 466), while below the crest of the ilium it is continuous with the fascia covering the Iliacus.

The *portion covering the Iliacus* is connected, laterally, to the whole length of the inner lip of the iliac crest; and medially, to the linea terminalis or brim of the lesser pelvis, where it blends with the periosteum. It is attached to the iliopectineal eminence where it receives the tendon of insertion of the Psoas minor, when that muscle exists. The external iliac vessels lie in front of it, but the branches of the lumbar plexus are behind it; it is separated from the peritoneum by a layer of subperitoneal areolar tissue (fascia of Abernethy).

Laterally to the femoral vessels, the iliac fascia is intimately connected to the posterior margin of the inguinal ligament, and is continuous with the transversalis fascia. It passes behind the femoral vessels, and beyond the inguinal ligament becomes the *iliopectineal fascia*. This fascia divides the space between the inguinal ligament and the hip-bone into two lacunæ or compartments, the medial of which transmits the femoral vessels, the lateral the Psoas major, the Iliacus and the femoral nerve. Medially to the vessels the iliopectineal fascia is attached to the pecten pubis, where it is continuous with the pectineal fascia. On the thigh the iliopectineal fascia covers the Iliacus and the Psoas major, and forms the posterior wall of the femoral sheath; in this region it is the deep layer of the fascia lata.

The **Psoas major** (fig. 572) is a long fusiform muscle placed on the side of the lumbar region of the vertebral column and the brim of the lesser pelvis. It arises (1) from the anterior surfaces and lower borders of the transverse processes of all the lumbar vertebræ; (2) by five slips or digitations, each of which takes origin from the bodies of two vertebræ and their intervertebral fibrocartilage: the highest slip arises from the lower margin of the body of the twelfth thoracic vertebra, the upper margin of the body of the first lumbar vertebra and the interposed fibrocartilage, the lowest slip from the adjacent margins of the bodies of the fourth and fifth lumbar vertebræ and the interposed fibrocartilage; (3) from a series of tendinous arches which extend across the constricted parts of the bodies of the lumbar vertebræ between the preceding slips; the lumbar arteries and veins, and filaments from the sympathetic trunk, pass beneath these tendinous arches. The muscle proceeds downwards across the brim of the lesser pelvis, and, diminishing gradually in size, passes behind the inguinal ligament and in front of the capsule of the hip-joint, and ends in a tendon: the latter receives nearly the whole of the fibres of the Iliacus and is inserted into the lower and posterior part of the lesser

FIG. 572.—Muscles of the iliac and anterior femoral regions.



trochanter of the femur. A large bursa, which may communicate with the cavity of the hip-joint, separates the tendon from the os pubis and the capsule of the joint.

Relations.—In the abdomen the Psoas major is in relation by its *anterior surface* with the medial lumbocostal arch, the fascia covering the muscle, the extraperitoneal fat and peritoneum, the kidney, Psoas minor, renal vessels, ureter, spermatic vessels, and genitofemoral nerve. In front of the right Psoas is the inferior vena cava and the terminal portion of the ileum, and in front of the left the colon. By its *posterior surface* it is in relation with the transverse processes of the lumbar vertebrae, and the Quadratus lumborum. The lumbar plexus is situated in the posterior part of the substance of the muscle. By its *medial side*, the muscle is in relation with the bodies of the lumbar vertebrae, the lumbar arteries, the gangliated trunk of the sympathetic, and the lumbar lymph glands; with the inferior vena cava on the right, and the aorta on the left side, and along the brim of the pelvis with the external iliac artery.

In the thigh it is in relation, in front, with the fascia lata; behind, with the capsule of the hip-joint, from which it is separated by a bursa; by its *medial border*, with the Pectineus and medial femoral circumflex artery, and also with the femoral artery, which slightly overlaps it; by its *lateral border*, with the Iliacus.

The femoral nerve descends at first through the fibres of Psoas major, then lies between it and the Iliacus, and at the level of the inguinal ligament is in front of the muscle.

The Psoas minor (fig. 572) is placed in front of the Psoas major. It arises from the sides of the bodies of the twelfth thoracic and first lumbar vertebrae and from the fibrocartilage between them. It ends in a long flat tendon which is inserted into the pecten pubis and iliopectineal eminence, and, by its lateral border, into the iliac fascia. This muscle is absent in about 40 per cent. of cases.

The Iliacus (fig. 572) is a flat, triangular muscle, which fills the iliac fossa. It arises from the upper two-thirds of this fossa, and from the inner lip of the iliac crest: behind, from the anterior sacro-iliac and the iliolumbar ligaments, and base of the sacrum; in front, it reaches as far as the anterior superior and anterior inferior iliac spines, and the notch between them. The fibres converge to be inserted into the lateral side of the tendon of the Psoas major, some of them being prolonged on to the body of the femur for about 2.5 cm. below and in front of the lesser trochanter.*

* The Psoas major and Iliacus are sometimes regarded as a single muscle named the *Iliopsoas*.

Relations.—Within the abdomen the Iliacus is in relation by its *anterior surface* with the iliac fascia, which separates the muscle from the extraperitoneal fat and peritonæum, and with the lateral femoral cutaneous nerve; on the right side, with the cæcum; on the left side, with the iliac part of the descending colon; by its *posterior surface*, with the iliac fossa; by its *medial border*, with the Psoas major and femoral nerve.

In the thigh, it is in relation, by its *anterior surface*, with the fascia lata, Rectus femoris, Sartorius, and arteria profunda femoris; by its *posterior surface*, with the capsule of the hip-joint, a bursa common to it and the Psoas major being interposed.

Nerves.—The Psoas major is supplied by branches of the second and third lumbar nerves, the Psoas minor by a branch of the first lumbar nerve, and the Iliacus by branches of the second and third lumbar nerves, through the femoral nerve.

* **Actions.**—The Psoas major, acting from above, flexes the thigh upon the pelvis, being assisted by the Iliacus; acting from below, with the femur fixed, it bends the lumbar portion of the vertebral column forwards and to its own side, and then, in conjunction with the Iliacus, tilts the pelvis forwards. When the muscles of both sides act from below, they serve to maintain the erect posture by supporting the vertebral column and pelvis upon the femora, or in continued action bend the trunk and pelvis forwards, as in raising the trunk from the recumbent posture.

The Psoas minor is a tensor of the iliac fascia.

Applied Anatomy.—There is no definite septum between the portions of fascia covering the Psoas and Iliacus respectively, and the fascia is only connected to the subjacent muscles by a quantity of loose connective tissue. When an abscess forms beneath this fascia, as it is very apt to do, the pus is contained in an osseofibrous cavity which is closed on all sides within the abdomen, and is open only at its lower part, where the fascia is prolonged over the muscles into the thigh.

Abscess within the sheath of the Psoas major (*psaos abscess*) is generally due to tuberculous caries of the bodies of the lower thoracic or the lumbar vertebrae. When the disease is in the thoracic region, the matter tracks down the posterior mediastinal cavity in front of the bodies of the vertebrae, and, passing beneath the medial lumbocostal arch, enters the sheath of the Psoas, down which it travels as far as the pelvic brim; it then gets beneath the iliac portion of the fascia, and fills up the iliac fossa. In consequence of the attachment of the fascia to the linea terminalis, it rarely finds its way into the lesser pelvis, but passes by a narrow opening under the inguinal ligament into the thigh, laterally to the femoral vessels. It thus follows that a psaos abscess may be described as consisting of four parts: (1) a somewhat narrow channel at its upper part, in the psaos sheath; (2) a dilated sac in the iliac fossa; (3) a constricted neck under the inguinal ligament; and (4) a dilated sac in the upper part of the thigh. When the lumbar vertebrae are the seat of the disease, the matter finds its way directly into the substance of the Psoas. The muscular fibres are destroyed, and the nerves contained in the abscess are isolated and exposed in its interior; the iliac vessels which lie in front of the fascia remain intact, and the peritonæum seldom becomes implicated. All psaos abscesses do not, however, pursue this course; the pus may leave the sheath of the muscle above the crest of the ilium, and tracking backwards may point in the loin (*lumbar abscess*); or it may point above the inguinal ligament in the inguinal region; or it may follow the course of the branches of the hypogastric vessels into the lesser pelvis, and, passing through the greater sciatic foramen, discharge itself on the back of the thigh.

II. MUSCLES OF THE THIGH

1. ANTERIOR FEMORAL MUSCLES (fig. 572)

Tensor fasciæ latæ.	Quadriceps	{ Rectus femoris. Vastus lateralis. Vastus medialis. Vastus intermedius.
Sartorius.	femoris	
Articularis genus.		

The superficial fascia forms a continuous layer over the whole of the thigh; it consists of areolar tissue containing in its meshes much fat, and may be separated into two or more layers, between which are found the superficial vessels and nerves. It varies in thickness in different parts of the limb; in the groin it is thick, and the two layers are separated from one another by the superficial inguinal lymph-glands, the great saphenous vein, and several smaller vessels. The superficial layer is continuous above with the superficial fascia of the abdomen. The deep layer of the superficial fascia is a

very thin, fibrous stratum, best marked on the medial side of the great saphenous vein and below the inguinal ligament. It is placed beneath the subcutaneous vessels and nerves and upon the surface of the fascia lata. It is intimately adherent to the fascia lata a little below the inguinal ligament. It covers the fossa ovalis (saphenous opening), being closely united to its circumference, and is connected to the sheath of the femoral vessels. The portion covering the fossa ovalis is perforated by the great saphenous vein and by blood and lymphatic vessels, hence it has been termed the *fascia cribrosa*, the openings for these vessels having been likened to the holes in a sieve. A large subcutaneous bursa is found in the superficial fascia over the patella.

The **deep fascia** of the thigh is named, from its great extent, the *fascia lata*: it constitutes an investment for the whole of this region of the limb, but varies in thickness in different parts. Thus, it is thicker in the upper and lateral part of the thigh, where it receives a fibrous expansion from the Glutæus maximus, and where the Tensor fasciæ latæ is inserted between its layers; it is very thin behind, and at the upper and medial part, where it covers the Adductor muscles, but becomes stronger around the knee, where it receives fibrous expansions from the tendon of the Biceps femoris laterally, from the Sartorius medially, and from the Quadriceps femoris in front. The fascia lata is attached, above and behind, to the back of the sacrum and coccyx; laterally, to the iliac crest; in front, to the inguinal ligament and to the superior ramus of the os pubis; and medially, to the inferior ramus of the os pubis, to the inferior ramus and tuberosity of the ischium, and to the lower border of the sacrotuberous ligament. From its attachment to the iliac crest it descends as a dense fascia over the Glutæus medius to the upper border of the Glutæus maximus, where it splits into two layers, one passing superficial and the other deep to this muscle; at the lower border of the muscle the two layers reunite. Laterally, the fascia lata receives the greater part of the insertion of the Glutæus maximus, and becomes proportionately thicker. The portion of the fascia lata attached to the front part of the iliac crest, and corresponding to the origin of the Tensor fasciæ latæ, extends down the lateral side of the thigh as two layers, one superficial and the other deep to this muscle; at the lower end of the muscle these two layers unite, and form a strong band, having first received the insertion of the muscle. This band is continued downwards, under the name of the *iliotibial tract* (iliotibial band), and is attached to the lateral condyle of the tibia. The part of the Iliotibial tract which lies deep to the Tensor fasciæ latæ is prolonged upwards to join the lateral part of the capsule of the hip-joint. The fascia lata is attached to all the prominent points around the knee-joint, viz. the condyles of the femur and tibia, and the head of the fibula. On either side of the patella it is strengthened by transverse fibres from the lower parts of the Vasti, which are attached to and support this bone. Of these the lateral are stronger, and are continuous with the iliotibial tract. The fascia lata gives off two strong intermuscular septa, which are attached to the whole length of the linea aspera of the femur and its prolongations above and below: the lateral and stronger septum, which extends from the insertion of the Glutæus maximus to the lateral condyle, separates the Vastus lateralis in front from the short head of the Biceps femoris behind, and gives partial origin to these muscles; the medial and thinner septum separates the Vastus medialis from the Adductors and the Pectineus. Besides these there are numerous smaller septa, separating the individual muscles, and enclosing each in a distinct sheath.

The **fossa ovalis** (saphenous opening) (fig. 573).—At the upper and medial part of the thigh, a little below the medial end of the inguinal ligament, is a large oval aperture in the fascia lata; it transmits the great saphenous vein, and other smaller vessels, and is termed the *fossa ovalis*. The *fascia cribrosa*, which is pierced by the structures passing through the opening, closes the aperture and must be removed to expose it. The fascia lata in this part of the thigh is described as consisting of a superficial and a deep portion.

The **superficial portion** of the fascia lata is the part on the lateral side of the fossa ovalis. It is attached to the crest and anterior superior spine of the ilium, to the whole length of the inguinal ligament, and to the pecten pubis in conjunction with the lacunar ligament. From the tubercle of the os pubis it is reflected downwards and lateralwards, as an arched margin, the *falciform*

margin, forming the lateral boundary of the fossa ovalis ; this margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels : to its edge is attached the fascia cribrrosa. The upward and medial prolongation of the falciform margin is named the *superior cornu* ; its downward and medial prolongation, the *inferior cornu*. The latter is well defined, and is continuous behind the great saphenous vein with the pectineal fascia.

The *deep portion* is situated on the medial side of the fossa ovalis, and is continuous with the superficial portion at the lower margin of the fossa : traced upwards, it covers the Pectineus, Adductor longus, and Gracilis, and, passing behind the sheath of the femoral vessels, to which it is closely united, is continuous with the iliopectineal fascia, and is attached to the pecten pubis.

FIG. 573.—The fossa ovalis



From this description it may be observed that the superficial portion of the fascia lata lies in front of the femoral vessels, and the deep portion behind them, so that an apparent aperture exists between the two, through which the great saphenous passes to join the femoral vein.

The **Tensor fasciæ latæ** arises from the anterior 5 cm. of the outer lip of the iliac crest ; from the outer surface of the anterior superior iliac spine, and part of the outer border of the notch below it, between the Glutæus medius and Sartorius ; and from the deep surface of the fascia lata. It is inserted between the two layers of the iliotibial tract of the fascia lata about the junction of the middle with the upper third of the thigh.

The **Sartorius**, the longest muscle in the body, is narrow and ribbon-like ; it arises by tendinous fibres from the anterior superior iliac spine and the upper half of the notch below it. It crosses obliquely the upper and anterior parts of the thigh, from the lateral to the medial side, then descends vertically,

as far as the medial side of the knee, passing behind the medial condyle of the femur to end in a tendon. This curves obliquely forwards and expands into a broad aponeurosis, which is inserted, in front of the Gracilis and Semitendinosus, into the upper part of the medial surface of the body of the tibia, nearly as far forwards as the anterior crest. The upper part of the aponeurosis is curved backwards over the upper edge of the tendon of the Gracilis so as to be inserted behind it. An offset, from its upper margin, blends with the capsule of the knee-joint, and another, from its lower border, with the fascia on the medial side of the leg.

The relations of this muscle to the femoral artery are important, as it constitutes the chief guide in tying the vessel. In the upper third of the thigh it forms the lateral side of a triangle, the *femoral (Scarpa's) triangle*, the medial side of which is formed by the medial border of the Adductor longus, and the base, directed upwards, by the inguinal ligament; the femoral artery passes through the middle of this space from its base to its apex. In the middle third of the thigh, the femoral artery is contained in the *adductor (Hunter's) canal*, on the roof of which the Sartorius lies.

The **Quadriceps femoris** is the great extensor muscle of the leg, and consists of a large fleshy mass which covers the front and sides of the femur. It is subdivided into separate portions, which have received distinctive names. One occupying the middle of the thigh, and connected above with the ilium, is called from its straight course the *Rectus femoris*. The other three lie in immediate connexion with the body of the femur, which they cover from the trochanters to the condyles; that on the lateral side of the femur is termed the *Vastus lateralis*; that on the medial side, the *Vastus medialis*; and that in front, the *Vastus intermedius*.

The **Rectus femoris** is fusiform in shape, and its superficial fibres are arranged in a bipennate manner, the deep fibres running straight down to the deep aponeurosis. It arises by two tendons: an anterior or straight, from the anterior inferior iliac spine, and a posterior or reflected, from a groove above the brim of the acetabulum. The two unite at an acute angle, and spread into an aponeurosis which is prolonged downwards on the anterior surface of the muscle, and from this the muscular fibres arise. The muscle ends in a broad and thick aponeurosis which occupies the lower two-thirds of its posterior surface, and, gradually becoming narrowed into a flattened tendon, is inserted into the base of the patella.

The **Vastus lateralis** is the largest part of the Quadriceps femoris. It arises by a broad aponeurosis, which is attached to the upper part of the intertrochanteric line, to the anterior and inferior borders of the greater trochanter, to the lateral lip of the gluteal tuberosity, and to the upper half of the lateral lip of the linea aspera: this aponeurosis covers the upper three-fourths of the muscle, and from its deep surface many fibres take origin. A few additional fibres arise from the tendon of the Gluteus maximus, and from the lateral intermuscular septum between the Vastus lateralis and short head of the Biceps femoris. The fibres form a large fleshy mass, which is attached to a strong aponeurosis, placed on the deep surface of the lower part of the muscle: this aponeurosis contracts into a flat tendon which is inserted into the lateral border of the patella, blending with the Quadriceps femoris tendon, and giving an expansion to the capsule of the knee-joint.

The Vastus medialis and Vastus intermedius appear to be inseparably united, but when the Rectus femoris has been reflected a narrow interval will be observed extending upwards from the medial border of the patella between the two muscles, and the separation may be carried to the lower part of the intertrochanteric line, where, however, the two muscles are frequently continuous.

The **Vastus medialis** arises from the lower half of the intertrochanteric line, the medial lip of the linea aspera, the upper part of the medial supracondylar line, the tendons of the Adductor longus and Adductor magnus, and the medial intermuscular septum. Its fibres are directed downwards and forwards, and are chiefly attached to an aponeurosis which lies on the deep surface of the muscle and is inserted into the medial border of the patella, and the Quadriceps femoris tendon, an expansion being sent to the capsule of the knee-joint.

The **Vastus intermedius** (*Crureus*) arises from the front and lateral surfaces of the body of the femur in its upper two-thirds and from the lower part of the lateral intermuscular septum. Its fibres end in a superficial aponeurosis, which forms the deep part of the *Quadriceps femoris* tendon.

The *tendons* of the different portions of the *Quadriceps* unite at the lower part of the thigh, to form a single strong tendon, which is inserted into the base of the patella, some fibres passing over it to blend with the *ligamentum patellæ*. More properly, the patella may be regarded as a sesamoid bone developed in the tendon of the *Quadriceps*; and the *ligamentum patellæ*, which is continued from the apex of the patella to the tuberosity of the tibia, as the proper tendon of insertion of the muscle, the medial and lateral *patellar retinacula* (p. 400) being expansions from its borders. A bursa, which usually communicates with the cavity of the knee-joint, is situated between the femur and the portion of the *Quadriceps* tendon above the patella; another is interposed between the tendon and the upper part of the front of the tibia (fig. 505).

The **Articularis genus** (*Subcrureus*) is a small muscle, usually distinct from the *Vastus intermedius*, but occasionally blended with it; it consists of several muscular bundles which arise from the anterior surface of the lower part of the body of the femur, and are inserted into the upper part of the capsule of the knee-joint.

Nerves.—The *Tensor fasciæ latæ* is supplied by the fourth and fifth lumbar and first sacral nerves through the superior gluteal nerve; the other muscles of this region, by the second, third, and fourth lumbar nerves, through the femoral nerve.

Actions.—The *Tensor fasciæ latæ* is a tensor of the *fascia lata*; continuing its action, the oblique direction of its fibres enables it to abduct the thigh and to rotate it inwards. In the erect posture, acting from below, it will serve to steady the pelvis upon the head of the femur; by means of the *iliotibial tract* it steadies the condyles of the femur on the articular surfaces of the tibia, and assists the *Glutæus maximus* in supporting the knee in the extended position. The *Sartorius* flexes the leg upon the thigh, and, continuing to act, flexes the thigh upon the pelvis; it next abducts and rotates the thigh outwards. When the knee is bent, the *Sartorius* assists the *Semitendinosus*, *Semimembranosus*, and *Popliteus* in rotating the tibia inwards. Taking its fixed point from the leg, it flexes the pelvis upon the thigh, and, if one muscle only acts, assists in rotating the pelvis. The *Quadriceps femoris* extends the leg upon the thigh. The *Rectus femoris* assists the *Psoas major* and *Iliacus* in supporting the pelvis and trunk upon the femur. It also assists in flexing the thigh on the pelvis, or if the thigh be fixed it will flex the pelvis. The *Vastus medialis* draws the patella medialwards as well as upwards.

Applied Anatomy.—A few fibres of the *Rectus femoris* are occasionally ruptured from severe strain. This accident is especially liable to occur during the games of football and cricket, and is sometimes known as 'cricket thigh.' The patient experiences a sudden pain in the part, as if he had been struck, and the *Rectus* stands out and is felt to be tense and rigid. The accident is often followed by considerable swelling from inflammatory effusion. Occasionally the *Quadriceps femoris* may be torn away from its insertion into the patella; or the *ligamentum patellæ* may be ruptured about 2·5 cm. above the bone. This accident is caused in the same manner as fracture of the patella by muscular action, viz. by a violent muscular effort to prevent falling while the knee is in a position of semi-flexion. A distinct gap can be felt above the patella, and, owing to the retraction of the muscular fibres, union may fail to take place.

2. MEDIAL FEMORAL MUSCLES

Gracilis.

Adductor longus.

Adductor magnus.

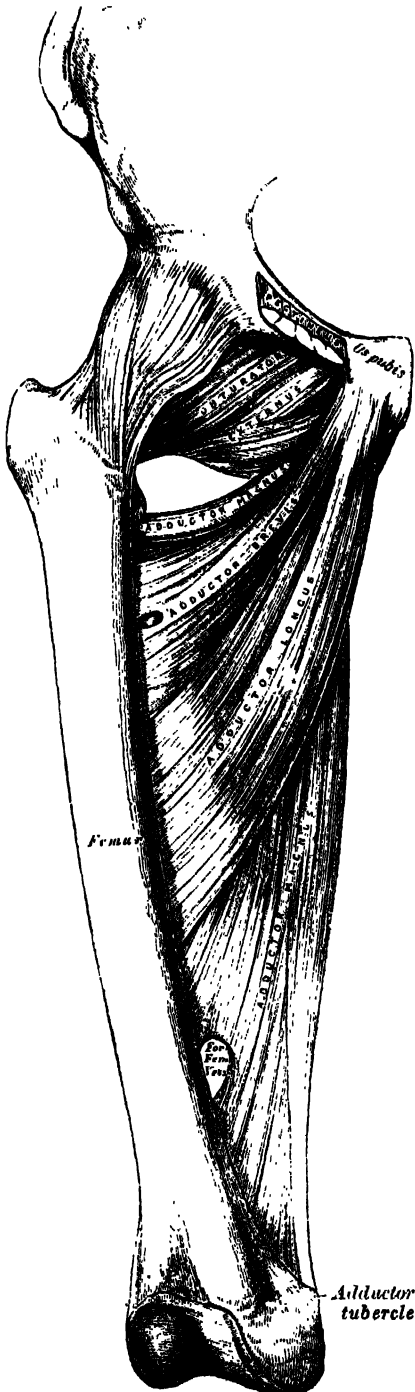
Pectineus.

Adductor brevis.

The **Gracilis** (fig. 572) is the most superficial muscle on the medial side of the thigh. It is thin and flattened, broad above, narrow and tapering below. It arises by a thin aponeurosis from the anterior margins of the lower half of the symphysis pubis and the upper half of the pubic arch. The fibres run vertically downwards, and end in a rounded tendon, which passes behind the medial condyle of the femur, curves round the medial condyle of the tibia, where it becomes flattened, and is inserted into the upper part of the medial surface

of the body of the tibia, below the condyle. A few of the fibres of the lower part of the tendon are prolonged into the deep fascia of the leg. At its

FIG. 574.—Deep muscles of the medial femoral region.



insertion the tendon is situated immediately above that of the Semitendinosus, and its upper edge is overlapped by the tendon of the Sartorius, with which it is in part blended. It is separated from the tibial collateral ligament of the knee-joint by a bursa common to it and the tendon of the Semitendinosus.

The **Pectineus** (fig. 572) is a flat, quadrangular muscle, situated at the anterior part of the upper and medial aspect of the thigh. It arises from the pecten pubis, and to a slight extent from the surface of bone in front of it, between the iliopectineal eminence and pubic tubercle, and from the fascia covering the anterior surface of the muscle; the fibres pass downwards, backwards, and lateralwards, to be inserted into the femur, along a line leading from the lesser trochanter to the linea aspera.

Relations.—Its *anterior surface* is in relation with the fascia lata, which separates it from the femoral vessels and great saphenous vein; its *posterior surface*, with the capsule of the hip-joint, the Adductor brevis, Obturator externus, and the anterior branch of the obturator nerve; its *lateral border*, with the Psoas major and the medial femoral circumflex vessels; its *medial border*, with the margin of the Adductor longus.

The **Adductor longus** (fig. 574), the most superficial of the three adductors, is a triangular muscle, lying in the same plane as the Pectineus. It arises by a flat, narrow tendon, from the front of the os pubis in the angle between the crest and the symphysis. It soon expands into a broad fleshy belly which passes downwards, backwards, and lateralwards, and is inserted, by an aponeurosis, into the middle third of the linea aspera of the femur, between the Vastus medialis and the Adductor magnus, with both of which it is usually blended.

Relations.—Its *anterior surface* is in relation with the fascia lata, the Sartorius, and, near its insertion, with the femoral artery and vein; its *posterior surface*, with the Adductores brevis and magnus, the anterior branch of the obturator nerve, and near its insertion with the profunda femoris vessels; its *lateral border*, with the Pectineus; its *medial border*, with the Gracilis.

The **Adductor brevis** (fig. 574) is situated immediately behind the two preceding muscles. It is somewhat triangular in form, and arises by a narrow origin from the outer surface of the inferior ramus of the os pubis, between

the Gracilis and Obturator externus. Its fibres, passing backwards, lateralwards, and downwards, are inserted, by an aponeurosis, into the femur, along the line leading from the lesser trochanter to the linea aspera and into the upper part of the linea aspera, immediately behind the Pectineus and upper part of the Adductor longus.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductor longus, arteria profunda femoris, and anterior branch of the obturator nerve; its *posterior surface*, with the Adductor magnus, and posterior branch of the obturator nerve; its *lateral border*, with the medial femoral circumflex artery, the Obturator externus, and conjoint tendon of the Psoas major and Iliacus: its *medial border*, with the Gracilis and Adductor magnus. It is pierced near its insertion by the second, or first and second, perforating branches of the arteria profunda femoris.

The **Adductor magnus** (fig. 574) is a large triangular muscle, situated on the medial side of the thigh. It arises from a small part of the inferior ramus of the os pubis, from the inferior ramus of the ischium, and from the lateral margin of the inferior part of the tuberosity of the ischium. Those fibres which arise from the ramus of the os pubis are short, horizontal in direction, and are inserted into the rough line leading from the greater trochanter to the linea aspera, medially to the Glutæus maximus*; those from the ramus of the ischium are directed downwards and lateralwards with different degrees of obliquity, to be inserted, by means of a broad aponeurosis, into the linea aspera and the upper part of its medial prolongation below. The medial portion of the muscle, composed principally of the fibres arising from the tuberosity of the ischium, forms a thick fleshy mass which descends almost vertically, and ends about the lower third of the thigh in a rounded tendon which is inserted into the adductor tubercle on the medial condyle of the femur, and is connected by a fibrous expansion to the line leading upwards from the tubercle to the linea aspera. At the insertion of the muscle, there is a series of osseo-aponeurotic openings, formed by tendinous arches attached to the bone. The upper four openings are small, and give passage to the perforating branches of the arteria profunda femoris. The lowest is of large size, and transmits the femoral vessels to the popliteal fossa.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductores brevis and longus, the femoral and profunda vessels, and the posterior branch of the obturator nerve; its *posterior surface*, with the sciatic nerve, the Glutæus maximus, Biceps femoris, Semitendinosus, and Semimembranosus. Its *superior border* lies parallel with the Quadratus femoris, the superficial branch of the medial femoral circumflex artery passing between them; its *medial border* is in relation with the Gracilis, Sartorius, and fascia lata.

Nerves.—The three Adductors and the Gracilis are supplied by the third and fourth lumbar nerves through the obturator nerve: the Adductor magnus receives an additional branch from the sacral plexus through the sciatic nerve. The Pectineus is supplied by the second, third, and fourth lumbar nerves through the femoral nerve, and by the third lumbar through the accessory obturator nerve when this latter exists. Occasionally it receives a branch from the obturator nerve.†

Actions.—The Pectineus and three Adductores adduct the thigh powerfully; they are especially used in horse exercise, the sides of the saddle being grasped between the knees by the contraction of these muscles; they rotate the thigh outwards, and when the limb has been abducted, they draw it medialwards, carrying the thigh across that of the opposite side. The Pectineus and Adductores brevis and longus assist the Psoas major and Iliacus in flexing the thigh upon the pelvis. In progression, all these muscles assist in drawing forwards the lower limb. The Gracilis assists the Sartorius in flexing the leg and rotating it inwards; it is also an adductor of the thigh. If the lower extremities be fixed, these muscles, taking their fixed points below, may act upon the pelvis, serving to maintain the body in

* These uppermost fibres are sometimes described as a separate muscle—the *Adductor minimus*—which is situated somewhat anteriorly to the other parts of the muscle.

† The Pectineus may consist of two incompletely separated strata: the lateral or dorsal stratum, which is constant, is supplied by a branch from the femoral nerve, or in the absence of this branch by the accessory obturator nerve; the medial or ventral stratum, when present, is supplied by the obturator nerve.—A. M. Paterson, *Journal of Anatomy and Physiology*, vol. xxvi. p. 43.

an erect posture; or, if their action be continued, flex the pelvis forwards upon the femur.

Applied Anatomy.—The Adductor longus is liable to be severely strained in those who ride much on horseback, or its tendon may be ruptured by suddenly gripping the saddle. Occasionally, especially in cavalry soldiers, the tendon becomes ossified, constituting the rider's bone.

3. MUSCLES OF GLUTEAL REGION (fig. 575)

Glutæus maximus.	Obturator internus.
Glutæus medius.	Gemellus superior.
Glutæus minimus.	Gemellus inferior.
Piriformis.	Quadratus femoris.
Obturator externus.	

The **Glutæus maximus**, the largest and most superficial muscle in the glutæal region, is a broad and thick fleshy mass of a quadrilateral shape, and forms the prominence of the nates. Its large size is one of the most characteristic features of the muscular system in man, connected as it is with the power he has of maintaining the trunk in the erect posture. The muscle is remarkably coarse in structure, being made up of fasciuli lying parallel with one another, and collected into large bundles separated by fibrous septa. It arises from the posterior glutæal line of the ilium, and the rough portion of bone, including the crest, immediately above and behind it: from the aponeurosis of the Sacrospinalis; from the posterior surface of the lower part of the sacrum and the side of the coccyx; from the sacrotuberous ligament, and from the fascia (glutæal aponeurosis) covering the Glutæus medius. The fibres run obliquely downwards and lateralwards; those forming the upper and larger portion of the muscle, together with the superficial fibres of the lower portion, end in a thick tendinous lamina, which passes across the greater trochanter, and is inserted into the iliotibial tract of the fascia lata; the deeper fibres of the lower portion of the muscle are inserted into the glutæal tuberosity of the femur between the Vastus lateralis and Adductor magnus.

Three *bursæ* are usually found in relation with the deep surface of this muscle. One, of large size, and generally multilocular, separates it from the greater trochanter; a second, often wanting, is situated on the tuberosity of the ischium; a third is found between the tendon of the muscle and that of the Vastus lateralis.

Relations.—Its *superficial surface* is in relation with a thin fascia which separates it from the subcutaneous tissue; its *deep surface*, with the ilium, sacrum, coccyx, and sacrotuberous ligament, part of the Glutæus medius, Piriformis, Gemelli, Obturator internus, Quadratus femoris, the tuberosity of the ischium, greater trochanter, the origins of the Biceps femoris, Semitendinosus, Semimembranosus, and the Adductor magnus. The superficial part of the superior glutæal artery reaches the deep surface of the muscle by passing between the Piriformis and the Glutæus medius; the inferior glutæal and internal pudendal vessels and the sciatic, pudendal, and lateral femoral cutaneous nerves, and muscular branches from the sacral plexus, issue from the pelvis below the Piriformis. The first perforating artery and the terminal branches of the medial circumflex femoral artery are also found under cover of the lower part of the muscle. Its *upper border* is thin, and is connected with the Glutæus medius by the glutæal aponeurosis. Its *lower border* is free and prominent, and is crossed by the fold of the nates.

The **Glutæus medius** is a broad, thick, radiating muscle, situated on the outer surface of the pelvis. Its posterior third is covered by the Glutæus maximus, its anterior two-thirds by the glutæal aponeurosis, which separates it from the superficial fascia and integument. It arises from the outer surface of the ilium between the iliac crest and posterior glutæal line above, and the anterior glutæal line below; it also arises from the strong fascia which covers the upper part of its outer surface. The fibres converge to a flattened tendon, which is inserted into the oblique ridge directed downwards and forwards on the lateral surface of the greater trochanter of the femur. A bursa separates the tendon of the muscle from the surface of the trochanter over which it glides.

The **Glutæus minimus**, the smallest of the three Glutæi, is placed immediately beneath the preceding. It is fan-shaped, arising from the outer surface

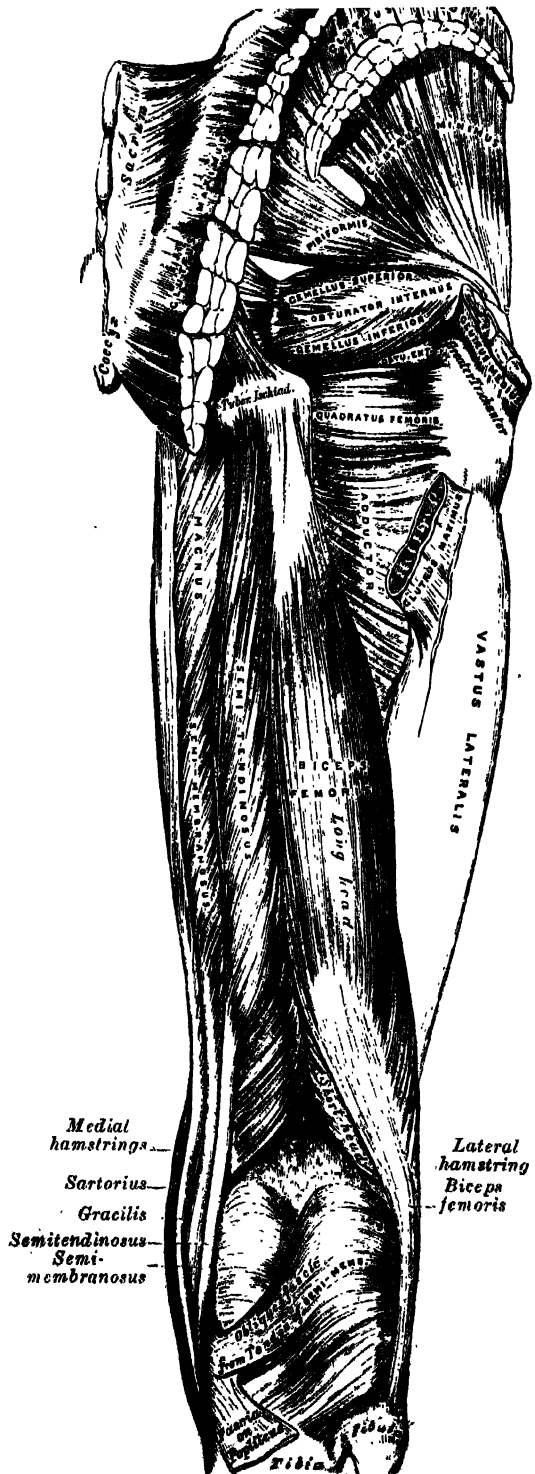
of the ilium, between the anterior and inferior gluteal lines, and behind, from the margin of the greater sciatic notch. The fibres converge to the deep surface of a radiated aponeurosis, and this ends in a tendon which is inserted into an impression on the anterior border of the greater trochanter of the femur, and gives an expansion to the capsule of the hip-joint. A bursa is interposed between the tendon and the greater trochanter.

Between the *Glutæus medius* and *Glutæus minimus* are the deep branches of the superior gluteal vessels and the superior gluteal nerve. The deep surface of the *Glutæus minimus* is in relation with the reflected tendon of the *Rectus femoris* and the capsule of the hip-joint.

The *Piriformis* lies almost parallel with the posterior margin of the *Glutæus medius*. It is situated partly within the pelvis against its posterior wall, and partly at the back of the hip-joint. It arises from the front of the sacrum by three fleshy digitations, attached to the portions of bone between the anterior sacral foramina, and to the grooves leading from the foramina: a few fibres also arise from the margin of the greater sciatic foramen, and from the anterior surface of the sacrotuberous ligament. The muscle passes out of the pelvis through the greater sciatic foramen, and is inserted by a rounded tendon into the upper border of the greater trochanter of the femur, behind and above, but often partly blended with, the common tendon of the *Obturator internus* and *Gemelli*.

Relations.—Within the pelvis the anterior surface of the *Piriformis* is in relation with the rectum (especially on the left side), the sacral plexus of nerves, and branches of the hypogastric vessels; its posterior surface with the sacrum. Outside the pelvis, its anterior surface is in contact

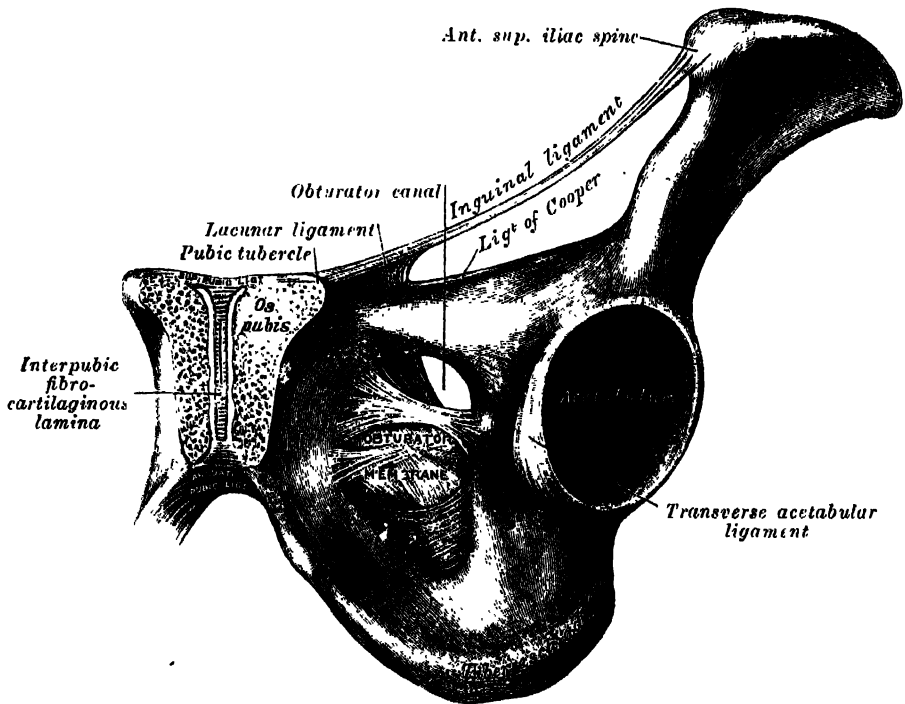
Fig. 575.—Muscles of the gluteal and posterior femoral regions.



with the posterior surface of the ischium and capsule of the hip-joint; and its *posterior surface*, with the *Glutæus maximus*. Its *upper border* is in relation with the *Glutæus medius*, and the superior glutæal vessels and nerve; its *lower border*, with the *Gemellus superior* and *Coccygeus*. The inferior glutæal and internal pudendal vessels, and the sciatic, posterior femoral cutaneous, and pudendal nerves, and muscular branches from the sacral plexus, appear on the buttock between the *Piriformis* and *Gemellus superior*. The muscle is frequently pierced by the common peronæal nerve.

The **Obturator membrane** (fig. 576) is a thin fibrous sheet, which almost completely closes the obturator foramen. Its fibres are arranged in interlacing bundles mainly transverse in direction; the uppermost bundle is attached to the obturator tubercles and completes the obturator canal for the passage of the obturator vessels and nerve. The membrane is attached to the sharp margin of the obturator foramen except at its lower lateral angle, where it is fixed to the pelvic surface of the inferior ramus of the ischium, i.e. within the margin. Both Obturator muscles are connected with this membrane.

FIG. 576.—The obturator membrane.



The **Obturator internus** is situated partly within the lesser pelvis, and partly at the back of the hip-joint. It arises from the inner surface of the anterolateral wall of the pelvis, where it surrounds the greater part of the obturator foramen, being attached to the inferior rami of the os pubis and ischium and to the inner surface of the hip-bone below and behind the pelvic brim, reaching from the upper part of the greater sciatic foramen above and behind to the obturator foramen below and in front. It also arises from the medial part of the pelvic surface of the obturator membrane, from the tendinous arch which completes the canal for the passage of the obturator vessels and nerve, and to a slight extent from the obturator fascia, which covers the muscle. The fibres converge rapidly towards the lesser sciatic foramen and end in four or five tendinous bands on the deep surface of the muscle; these bands are reflected at a right angle over the grooved surface of the ischium between its spine and tuberosity. The grooved surface is covered by smooth cartilage, which is separated from the tendon by a bursa, and presents one or more ridges corresponding with the furrows between the tendinous bands. These bands leave the pelvis through the lesser sciatic

foramen and unite into a single flattened tendon, which passes horizontally across the capsule of the hip-joint, and, after receiving the attachments of the Gemelli, is inserted into the fore part of the medial surface of the greater trochanter of the femur, above and in front of the trochanteric fossa. A bursa, narrow and elongated in form, is usually found between the tendon and the capsule of the hip-joint; it occasionally communicates with the bursa between the tendon and the ischium.

Relations.—*Within the pelvis*, the anterolateral surface of the muscle is in relation with the obturator membrane and inner surface of the anterior wall of the pelvis; its pelvic surface, with the obturator fascia, and the origin of the Levator ani, and with the internal pudendal vessels and pudendal nerve, which cross it. The pelvic surface forms the lateral boundary of the ischiorectal fossa. *Outside the pelvis*, the muscle is covered by the Glutæus maximus, crossed by the sciatic nerve, and rests on the back of the hip-joint. As the tendon of the Obturator internus emerges from the lesser sciatic foramen it is overlapped both in front and behind by the two Gemelli which form a muscular canal for it; near its insertion the Gemelli pass in front of the tendon and form a groove in which it lies.

The **Gemelli** are two small muscular fasciculi, accessories to the tendon of the Obturator internus which is received into a groove between them.

The **Gemellus superior**, the smaller of the two, arises from the outer surface of the spine of the ischium, blends with the upper part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter of the femur. It is sometimes wanting.

The **Gemellus inferior** arises from the upper part of the tuberosity of the ischium, immediately below the groove for the Obturator internus tendon. It blends with the lower part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter.

The **Quadratus femoris** is a flat, quadrilateral muscle, between the Gemellus inferior and the upper margin of the Adductor magnus; it is separated from the latter by the superficial branch of the medial femoral circumflex artery. It arises from the upper part of the external border of the tuberosity of the ischium, and is inserted into the upper part of the linea quadrata of the femur. A bursa is often found between the front of this muscle and the lesser trochanter.

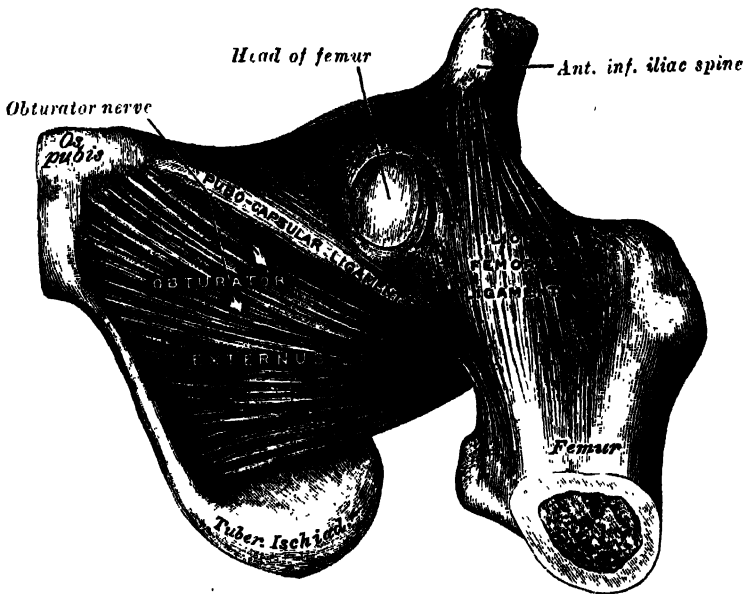
The **Obturator externus** (fig. 577) is a flat, triangular muscle, which covers the outer surface of the anterior wall of the pelvis. It arises from the margin of bone immediately around the medial side of the obturator foramen, viz. from the rami of the os pubis, and the inferior ramus of the ischium; it also arises from the medial two-thirds of the outer surface of the obturator membrane, and from the tendinous arch which completes the canal for the passage of the obturator vessels and nerves. The fibres springing from the inferior ramus of the ischium extend on to the inner surface of the bone, where they obtain a narrow origin between the margin of the foramen and the attachment of the obturator membrane. The fibres converge and pass backwards, laterally, and upwards, and end in a tendon which runs across the back of the neck of the femur and lower part of the capsule of the hip-joint and is inserted into the trochanteric fossa of the femur. The obturator vessels lie between the muscle and the obturator membrane; the anterior branch of the obturator nerve reaches the thigh by passing in front of the muscle, and the posterior branch by piercing it.

Nerves.—The Glutæus maximus is supplied by the fifth lumbar and first and second sacral nerves through the inferior gluteal nerve; the Glutæi medius and minimus by the fourth and fifth lumbar and first sacral nerves through the superior gluteal nerve; the Piriformis is supplied by the first and second sacral nerves; the Gemellus inferior and Quadratus femoris by the last lumbar and first sacral nerves; the Gemellus superior and Obturator internus by the first, second, and third sacral nerves, and the Obturator externus by the third and fourth lumbar nerves through the obturator nerve.

Actions.—When the Glutæus maximus takes its fixed point from the pelvis, it extends the femur and brings it into line with the trunk. Taking its fixed point below, it supports the pelvis and the trunk upon the head of the femur; this is especially obvious in standing on one leg. Its most powerful action is to raise the

trunk after stooping, by drawing the pelvis backwards, being assisted in this action by the Semitendinosus, Semimembranosus and long head of the Biceps femoris. The Glutæus maximus is a tensor of the fascia lata, and by its connexion with the iliotibial tract steadies the femur on the articular surfaces of the tibia during standing, when the Extensor muscles are relaxed. The lower part of the muscle also acts as an adductor and external rotator of the limb. The Glutæi medius and minimus

FIG. 577.—The Obturator externus.



abduct the thigh when the limb is extended, and are principally called into action in supporting the body on one limb, in conjunction with the Tensor fasciæ latæ. Their anterior fibres draw the greater trochanter forwards and rotate the thigh inwards, in which action they are also assisted by the Tensor fasciæ latæ. The remaining muscles are powerful external rotators of the thigh. When the thigh is flexed upon the pelvis, they cease to act as rotators, and become abductors, with the exception of the Obturator externus, which still rotates the femur outwards.

4. POSTERIOR FEMORAL MUSCLES (fig. 575)

Biceps femoris.

Semitendinosus.

Semimembranosus.

The **Biceps femoris** is situated on the posterolateral aspect of the thigh. It has two heads of origin : one, the long head, arises from the lower and medial impression on the back part of the tuberosity of the ischium, by a tendon common to it and the Semitendinosus, and from the lower part of the sacrotuberous ligament ; the other, the short head, from the lateral lip of the linea aspera of the femur, between the Adductor magnus and Vastus lateralis, extending up almost as high as the insertion of the Glutæus maximus ; from the lateral prolongation of the linea aspera to within 5 cm. of the lateral condyle ; and from the lateral intermuscular septum. The fibres of the long head form a fusiform belly, which passes obliquely downwards and lateralwards across the sciatic nerve to end in an aponeurosis ; this aponeurosis covers the posterior surface of the muscle, receives on its deep surface the fibres of the short head, and gradually contracts into a tendon, which is inserted into the lateral side of the head of the fibula, and by a small slip into the lateral condyle of the tibia. This tendon forms the lateral hamstring and divides into two portions which embrace the fibular collateral ligament of the knee-joint ; from its

posterior border a thin expansion is given off to the fascia of the leg. The common peronæal nerve descends along its medial border.

The **Semitendinosus**, remarkable for the great length of its tendon of insertion, is situated at the posterior and medial aspect of the thigh. It arises from the lower and medial impression on the tuberosity of the ischium, by a tendon common to it and the long head of the Biceps femoris; it also arises from an aponeurosis connecting the adjacent surfaces of the two muscles to the extent of about 7.5 cm. from their origin. The muscle is fusiform and ends a little below the middle of the thigh in a long round tendon which lies along the medial side of the popliteal fossa; the tendon curves around the medial condyle of the tibia, passes over the tibial collateral ligament of the knee-joint, from which it is separated by a bursa, and is inserted into the upper part of the medial surface of the body of the tibia behind the insertion of the Sartorius and below that of the Gracilis. At its insertion it is united with the tendon of the Gracilis and gives off a prolongation to the deep fascia of the leg. A tendinous intersection is usually observed about the middle of the muscle.

The **Semimembranosus**, so called from its membranous tendon of origin, is situated at the back and medial side of the thigh. It arises by a thick tendon from the upper and lateral impression on the tuberosity of the ischium, above and laterally to the Biceps femoris and Semitendinosus, and is inserted into the groove on the back of the medial condyle of the tibia. The tendon of origin expands into an aponeurosis, which passes downwards under cover of the Semitendinosus and long head of the Biceps femoris; from this aponeurosis muscular fibres arise, and converge to another aponeurosis which covers the lower part of the posterior surface of the muscle and contracts into the tendon of insertion. The tendon of insertion gives off certain fibrous expansions: one, of considerable size, passes upwards and lateralwards to be inserted into the back part of the lateral condyle of the femur, forming part of the oblique popliteal ligament of the knee-joint; a second is continued downwards to the fascia which covers the Popliteus muscle; while a few fibres join the tibial collateral ligament of the knee-joint and the fascia of the leg. The muscle overlaps the upper part of the popliteal vessels.

The tendons of insertion of the Semitendinosus and Semimembranosus form the medial hamstrings.

Nerves.—The three muscles are supplied by the fourth and fifth lumbar and the first, second, and third sacral nerves; the short head of the Biceps femoris receives its nerve from the common peronæal nerve; the Semitendinosus, Semimembranosus, and long head of the Biceps femoris are supplied through the tibial nerve.

Actions.—The hamstring muscles flex the leg upon the thigh. When the knee is semiflexed, the Biceps femoris in consequence of its oblique direction rotates the leg slightly outwards; and the Semitendinosus, and to a slight extent the Semimembranosus, rotate the leg inwards, assisting the Popliteus. Taking their fixed point from below, these muscles serve to support the pelvis upon the head of the femur, and to draw the trunk directly backwards, as in raising it from the stooping position or in feats of strength, when the body is thrown backwards in the form of an arch. As already indicated on p. 346, complete flexion of the hip cannot be effected unless the knee-joint is also flexed, on account of the shortness of the hamstring muscles.

Applied Anatomy.—In disease of the knee-joint, contraction of the hamstring tendons is a frequent complication; this causes flexion of the leg, and a partial dislocation of the tibia backwards, with a slight degree of rotation outwards, probably due to the action of the Biceps femoris. The hamstring tendons occasionally require subcutaneous division in some forms of spurious ankylosis of the knee-joint dependent upon permanent contraction and rigidity of the muscles, or from contracture of the ligamentous and other tissues surrounding the joint, the result of disease. The relation of the common peronæal nerve, which lies in close apposition to the medial border of the tendon of the Biceps femoris, must always be borne in mind in dividing this tendon, and a free incision with exposure of the tendon, before division, is the safer proceeding.

III. MUSCLES OF THE LEG

The muscles of the leg may be divided into three groups : anterior, posterior and lateral.

1. ANTERIOR CRURAL MUSCLES (fig. 578)

Tibialis anterior.

Extensor hallucis longus.

Extensor digitorum longus.

Peronæus tertius.

The **fascia cruris** or **deep fascia** of the leg is continuous above with the fascia lata, and is attached around the knee to the patella, the ligamentum patellæ, the tuberosity and condyles of the tibia, and the head of the fibula. Behind, it forms the popliteal fascia which covers the popliteal fossa ; here it is strengthened by transverse fibres, and perforated by the small saphenous vein. It receives an expansion from the tendon of the Biceps femoris laterally, and expansions from the tendons of the Sartorius, Gracilis, Semitendinosus, and Semimembranosus medially ; it blends with the periosteum covering the subcutaneous surface of the tibia, and with that covering the head and malleolus of the fibula ; below, it is continuous with the transverse crural and lacinate ligaments. It is thick and dense in the upper and anterior part of the leg, and gives origin, by its deep surface, to some fibres of the Tibialis anterior and Extensor digitorum longus ; it is thinner behind, where it covers the Gastrocnemius and Soleus. On the lateral side of the leg it gives off the *anterior and posterior fibular intermuscular septa* which are attached respectively to the anterolateral and posterolateral borders of the fibula ; in the anterior and posterior crural regions the fascia also gives off several slender processes which enclose the individual muscles. A broad transverse intermuscular septum, called the *deep transverse fascia of the leg*, intervenes between the superficial and deep posterior crural muscles.

The **Tibialis anterior** is situated on the lateral side of the tibia ; it is thick and fleshy above, tendinous below. It arises from the lateral condyle and upper half or two-thirds of the lateral surface of the body of the tibia ; from the adjoining part of the anterior surface of the interosseous membrane ; from the deep surface of the fascia cruris ; and from the intermuscular septum between it and the Extensor digitorum longus. The fibres run vertically downwards, and end in a tendon which is apparent on the anterior surface of the muscle at the lower third of the leg ; after passing through the medial compartments of the transverse and cruciate crural ligaments, it is inserted into the medial and under surfaces of the first cuneiform bone, and the base of the first metatarsal bone. This muscle overlaps the anterior tibial vessels and deep peronæal nerve in the upper part of the leg.

The **Extensor hallucis longus** is a thin muscle, situated between the Tibialis anterior and the Extensor digitorum longus. It arises from the anterior surface of the fibula for about the middle two-fourths of its extent, medially to the origin of the Extensor digitorum longus ; it also arises from the anterior surface of the interosseous membrane to a similar extent. The anterior tibial vessels and deep peronæal nerve lie between it and the Tibialis anterior. The fibres pass downwards, and end in a tendon, which occupies the anterior border of the muscle, passes through a compartment in the cruciate crural ligament, crosses to the medial side of the anterior tibial vessels near the ankle-joint, and is inserted into the base of the distal phalanx of the great toe. Opposite the metatarsophalangeal articulation a thin prolongation is given off from either side of the tendon and covers the dorsal surface of the joint. An expansion from the medial side of the tendon is usually inserted into the base of the proximal phalanx.

The **Extensor digitorum longus** is a pennate muscle, situated at the lateral part of the front of the leg. It arises from the lateral condyle of the tibia, the upper three-fourths of the anterior surface of the body of the fibula, the upper part of the anterior surface of the interosseous membrane, the deep surface of the fascia cruris, the anterior fibular intermuscular septum and the septum between it and the Tibialis anterior. Between it and the Tibialis

anterior are the upper portions of the anterior tibial vessels and deep peronæal nerve. The tendon passes under the transverse and cruciate crural ligaments in company with the Peronæus tertius, and divides into four slips, which run forward on the dorsum of the foot, and are inserted into the second and third phalanges of the four lesser toes. The tendons to the second, third, and fourth toes are each joined, opposite the metatarsophalangeal articulation, on the lateral side by a tendon of the Extensor digitorum brevis. The tendons are inserted as follows: each receives a fibrous expansion from the corresponding Lumbricalis and Interossei, and then spreads out into a broad aponeurosis, which covers the dorsal surface of the first phalanx: at the articulation of the first with the second phalanx this aponeurosis divides into three slips—an intermediate, which is inserted into the base of the second phalanx; and two collateral slips, which, after uniting with one another on the dorsal surface of the second phalanx, are inserted into the base of the third phalanx.

The *Peronæus tertius* is a part of the *Extensor digitorum longus*, and might be described as its fifth tendon. The fibres belonging to this tendon arise from the lower third or more of the anterior surface of the fibula, the lower part of the anterior surface of the interosseous membrane, and the anterior fibular intermuscular septum. The tendon passes under the transverse and cruciate crural ligaments in the same compartment as the *Extensor digitorum longus*, and is inserted into the dorsal surface of the base of the fifth metatarsal bone, but often spreads into a thin sheet which extends forwards along the shaft of the bone. This muscle is sometimes wanting.

Nerves.—These muscles are supplied by the fourth and fifth lumbar and first sacral nerves through the deep peronæal nerve.

Actions.—The *Tibialis anterior* and *Peronæus tertius* are the direct flexors of the foot at the ankle-joint; the former muscle, when acting in conjunction with the *Tibialis posterior*, raises the medial border of the foot (i.e. inverts the foot); and the latter, acting with the *Peronæi brevis* and *longus*, raises the lateral border of the foot (i.e. everts the foot). The *Extensor digitorum longus* and *Extensor hallucis longus* extend the phalanges of the toes, and, continuing their action, flex the foot upon the leg. Taking their fixed points from below, in the erect posture, all these muscles serve to fix the bones of the leg in the perpendicular position and give increased strength to the ankle-joint.

FIG. 578.—Muscles of the front of the leg.



2. POSTERIOR CRURAL MUSCLES

The muscles of the back of the leg are subdivided into two groups—superficial and deep. Those of the superficial group constitute a

powerful muscular mass, forming the calf of the leg. Their large size is one of the most characteristic features of the muscular apparatus in man, and bears a direct relation to his erect attitude and his mode of progression.

Fig. 579.—Muscles of the back of the leg.—Superficial group.

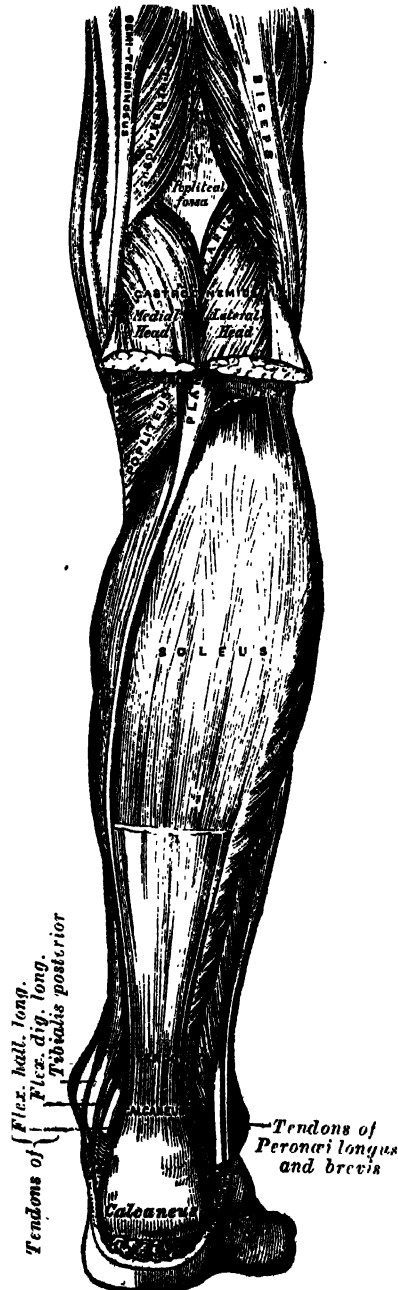
Superficial Group (fig. 579)

Gastrocnemius. Soleus. Plantaris.

The **Gastrocnemius** is the most superficial muscle, and forms the greater part of the calf. It arises by two heads, which are connected to the condyles of the femur by strong, flat tendons. The medial and larger head takes its origin from a depression at the upper and posterior part of the medial condyle behind the adductor tubercle, and from a rounded tubercle on the popliteal surface of the femur just above the medial condyle. The lateral head arises from an impression on the lateral surface of the lateral condyle and from the lower part of the corresponding epicondylar ridge. Both heads also arise from the subjacent part of the articular capsule of the knee-joint. Each head spreads out into a tendinous expansion which covers the posterior surface of the corresponding part of the muscle. From the anterior surfaces of these tendinous expansions, muscular fibres are given off; those of the medial head being thicker and extending lower than those of the lateral. The fibres unite at an angle in the middle line of the muscle in a tendinous raphe, which expands into a broad aponeurosis on the anterior surface of the muscle, and into this the remaining fibres are inserted. The aponeurosis, gradually contracting, unites with the tendon of the Soleus, and forms with it the tendo calcaneus.

Relations.—The fascia cruris separates the superficial surface of the muscle from the small saphenous vein, and the peroneal anastomotic, medial sural cutaneous, and sural nerves; the common peroneal nerve crosses the lateral head of the muscle, lying partly under cover of Biceps femoris. The deep surface is in relation with the oblique popliteal ligament of the knee-joint, the Popliteus, Soleus, Plantaris, popliteal vessels, and tibial nerve. In front of the tendon of the medial head is a bursa, which, in some cases, communicates with the cavity of the knee-joint. The tendon of the lateral head sometimes contains a sesamoid fibrocartilage or bone, where it plays over the corresponding condyle; and one is occasionally found in the tendon of the medial head.

The **Soleus** is a broad flat muscle situated immediately in front of the Gastrocnemius. It arises by tendinous fibres from the back of the head, and from the upper fourth of the posterior surface of the body of the fibula; from the popliteal line and the middle third of the medial border of the tibia; and from a fibrous band which stretches between these origins and arches over the popliteal vessels and tibial nerve. The tendinous origins from the tibia and



fibula expand and join one another to form a well-marked, coronally placed, intramuscular septum, the anterior and posterior surfaces of which constitute the immediate attachment of the majority of the muscular fibres. The muscular fibres end in an aponeurosis, which covers the posterior surface of the muscle, and, gradually becoming thicker and narrower, joins with the tendon of the Gastrocnemius, and forms with it the tendo calcaneus.

Relations.—Its *superficial surface* is in relation with the Gastrocnemius and Plantaris; its *deep surface*, with the Flexor digitorum longus, Flexor hallucis longus, Tibialis posterior, and posterior tibial vessels and nerve, from all of which it is separated by the deep transverse fascia of the leg.

The Gastrocnemius and Soleus together form a muscular mass which is occasionally described as the *Triceps suræ*; its tendon of insertion is the tendo calcaneus.

The **tendo calcaneus** (tendo Achillis), the common tendon of the Gastrocnemius and Soleus, is the thickest and strongest in the body. It is about 15 cm. long, and begins near the middle of the leg, but receives fleshy fibres on its anterior surface, almost to its lower end. It gradually narrows and thickens until it reaches a level about 4 cm. above the calcaneus; below this level it expands and is inserted into the middle part of the posterior surface of the calcaneus, a bursa being interposed between the tendon and the upper part of this surface.

The **Plantaris** arises from the lower part of the lateral prolongation of the linea aspera, and from the oblique popliteal ligament of the knee-joint. It forms a small fusiform belly, from 7 cm. to 10 cm. long; this ends in a long slender tendon which crosses obliquely between the Gastrocnemius and Soleus, and runs along the medial border of the tendo calcaneus, to be inserted with it into the posterior part of the calcaneus. This muscle is sometimes double, and at other times wanting. Occasionally, its tendon is lost in the lacinate ligament, or in the fascia of the leg.

Nerves.—The Gastrocnemius and Soleus are supplied by the first and second sacral nerves, and the Plantaris by the fourth and fifth lumbar and first sacral nerves, through the tibial nerve.

Actions.—The muscles of the calf are the chief extensors of the foot at the ankle-joint. They possess considerable power, and are called into use in standing, walking, dancing, and leaping; hence the large size they usually present. In walking, these muscles raise the heel from the ground; the body being thus supported on the raised foot, the opposite limb can be carried forwards. In standing, the Soleus, taking its fixed point from below, steadies the leg upon the foot. The Gastrocnemius, acting from below, serves to flex the femur upon the tibia. The Plantaris is the rudiment of a large muscle, the tendon of which in some of the lower animals is continued over the calcaneus to be inserted into the plantar aponeurosis: in man it is an accessory to the Gastrocnemius, extending the ankle if the foot be free, or bending the knee if the foot be fixed.

Deep Group (fig. 580)

Popliteus.

Flexor hallucis longus.

Flexor digitorum longus.

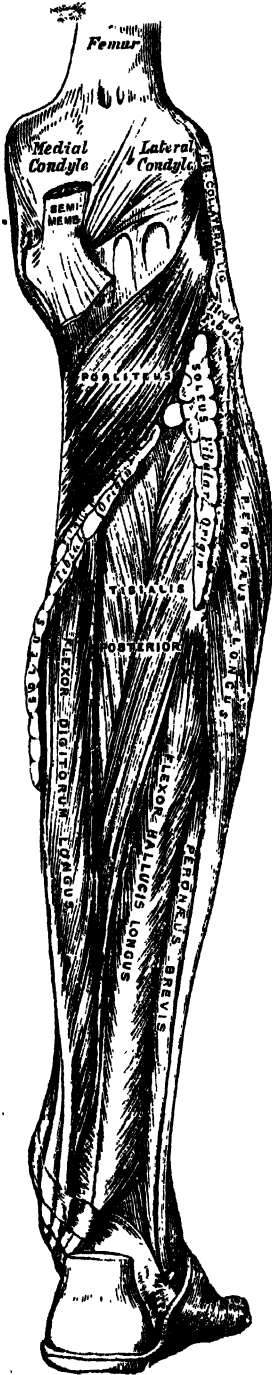
Tibialis posterior.

The **deep transverse fascia** of the leg is a septum between the superficial and deep muscles of the back of the leg. At the sides it is connected to the medial margin of the tibia and the posterolateral border of the fibula. Above, where it covers the Popliteus, it is thick and dense, and receives an expansion from the tendon of the Semimembranosus; it is thinner in the middle of the leg; but below, where it covers the tendons passing behind the malleoli, it is thickened and continuous with the lacinate ligament.

The **Popliteus** is a thin, flat, triangular muscle, which forms the lower part of the floor of the popliteal fossa. It arises by a strong tendon about 2.5 cm. long, from a depression at the anterior part of the groove on the lateral condyle of the femur, and to a small extent from the oblique popliteal ligament of the knee-joint. It is inserted into the medial two-thirds of the triangular surface

above the popliteal line on the posterior surface of the body of the tibia, and into the tendinous expansion covering the muscle.

FIG. 580.—Muscles of the back of the leg. Deep group.



Relations.—Its tendon of origin is covered by the tendon of the Biceps femoris and by the fibular collateral ligament of the knee-joint: it grooves the posterior border of the lateral meniscus, and is invested by the synovial stratum of the capsule of the knee-joint. The fascia covering the muscle separates it from the Gastrocnemius, Plantaris, popliteal vessels, and tibial nerve. The deep surface of the muscle is in contact with the oblique popliteal ligament of the knee-joint and the back of the tibia.

The **Flexor hallucis longus** is situated on the fibular side of the leg. It arises from the inferior two-thirds of the posterior surface of the body of the fibula, with the exception of about 2.5 cm. at its lowest part; from the lower part of the interosseous membrane; from the posterior fibular intermuscular septum, and from the fascia covering the Tibialis posterior. The fibres pass obliquely downwards and backwards, and end in a tendon which occupies nearly the whole length of the posterior surface of the muscle. This tendon lies in a groove which crosses the posterior surface of the lower end of the tibia, the posterior surface of the talus, and the under surface of the sustentaculum tali of the calcaneus. In the sole of the foot it runs forwards between the two heads of the Flexor hallucis brevis, and is inserted into the base of the distal phalanx of the great toe. The grooves on the talus and calcaneus, which contain the tendon of the muscle, are converted by tendinous fibres into a canal which is lined by a mucous sheath. As the tendon passes forwards in the sole of the foot, it is situated above, and crosses from the lateral to the medial side of, the tendon of the Flexor digitorum longus, to which it is connected by a fibrous slip.

Relations.—Its *superficial surface* is in relation with the Soleus and tendo calcaneus, from which it is separated by the deep transverse fascia; its *deep surface*, with the fibula, Tibialis posterior, the peroneal vessels, the lower part of the interosseous membrane, and the ankle-joint; its *lateral border*, with the Peronei; its *medial border*, with the Tibialis posterior, posterior tibial vessels and tibial nerve.

The **Flexor digitorum longus** is situated on the tibial side of the leg. At its origin it is thin and pointed, but it gradually increases in size as it descends. It arises from the posterior surface of the body of the tibia, medially to the tibial origin of the Tibialis posterior; this origin extends from immediately below the popliteal line to within 7 cm. or 8 cm. of the lower extremity of the bone; it also arises from the fascia covering the Tibialis posterior.

The fibres end in a tendon, which runs nearly the whole length of the posterior surface of the muscle. This tendon passes behind the medial malleolus, in a groove common to it and the Tibialis posterior, but separated from the latter by a fibrous septum; each tendon being contained in a special compartment lined

by a separate mucous sheath. It passes obliquely forwards and lateralwards, superficially to the deltoid ligament of the ankle-joint, and deep to the lacinate ligament, and enters the sole of the foot (fig. 584), where it crosses below the tendon of the Flexor hallucis longus, and receives from it a strong tendinous slip. It then expands and is joined by the Quadratus plantæ, and finally divides into four tendons, which are inserted into the bases of the last phalanges of the second, third, fourth, and fifth toes, each tendon passing through an opening in the corresponding tendon of the Flexor digitorum brevis opposite the base of the first phalanx.

Relations.—In the leg its *superficial surface* is in relation with the posterior tibial vessels and tibial nerve, and the deep transverse fascia which separates it from the Soleus; its *deep surface*, with the tibia and Tibialis posterior. In the foot, it is covered by the Abductor hallucis and Flexor digitorum brevis, and crosses superficially to the Flexor hallucis longus.

The Tibialis posterior lies between the Flexor hallucis longus and Flexor digitorum longus, and is the deepest muscle on the back of the leg. It begins above by two pointed processes, separated by an angular interval through which the anterior tibial vessels pass to the front of the leg. It arises from the whole of the posterior surface of the interosseous membrane, with the exception of its lowest part; from the lateral portion of the posterior surface of the body of the tibia, between the commencement of the popliteal line above and the junction of the middle with the lower third of the body below; and from the upper two-thirds of the medial surface of the fibula; some fibres also arise from the deep transverse fascia, and from the intermuscular septa separating it from the adjacent muscles. In the lower fourth of the leg its tendon passes in front of that of the Flexor digitorum longus and lies with it in a groove behind the medial malleolus, but enclosed in a separate sheath; it next passes under the lacinate and over the deltoid ligament into the foot, and then below the plantar calcaneonavicular ligament, where it contains a sesamoid fibrocartilage. It is inserted into the tuberosity of the navicular bone, and gives off fibrous slips, one of which passes backwards and is attached to the sustentaculum tali of the calcaneus, while others pass forwards and lateralwards and are fixed to the three cuneiform bones, the cuboid bone, and the bases of the second, third, and fourth metatarsal bones.

Relations.—Its *superficial surface* is in relation with the Soleus, from which it is separated by the deep transverse fascia, the Flexor digitorum longus, the posterior tibial vessels and tibial nerve, and the peroneal vessels; its *deep surface* with the interosseous membrane, the tibia, fibula, and ankle-joint.

Nerves.—The Popliteus is supplied by the fourth and fifth lumbar and first sacral nerves, the Flexor digitorum longus and Tibialis posterior by the fifth lumbar and first sacral, and the Flexor hallucis longus by the fifth lumbar and the first and second sacral nerves, all through the tibial nerve.

Actions.—The Popliteus assists in flexing the leg upon the thigh; when the leg is flexed, it will rotate the tibia inwards. It is especially called into action at the beginning of the act of bending the knee, inasmuch as it produces the slight inward rotation of the tibia which is essential in the early stage of this movement. The Tibialis posterior is a direct extensor of the foot at the ankle-joint; acting in conjunction with the Tibialis anterior, it turns the sole of the foot upwards and medialwards (i.e. inverts the foot), antagonising the Peronæi, which turn it upwards and lateralwards (evert it). In the sole of the foot the tendon of the Tibialis posterior lies directly below the plantar calcaneonavicular ligament, and is therefore an important factor in maintaining the arch of the foot. The Flexor digitorum longus and Flexor hallucis longus are the direct flexors of the phalanges, and, continuing their action, extend the foot upon the leg; they assist the Gastrocnemius and Soleus in extending the foot, as in the act of walking, or in standing on tiptoe. In consequence of the oblique direction of its tendons the Flexor digitorum longus would draw the toes medialwards, were it not for the Quadratus plantæ, which, inserted into the lateral side of the tendon, draws it to the middle line of the foot. Taking their fixed point from the foot, these muscles serve to maintain the upright posture by steadying the tibia and fibula perpendicularly upon the talus.

3. LATERAL CRURAL MUSCLES (fig. 580)

*Peronæus longus.**Peronæus brevis.*

The *Peronæus longus* is situated at the upper part of the lateral side of the leg, and is the more superficial of the two muscles. It arises from the head, and upper two-thirds of the lateral surface of the body, of the fibula, from the deep surface of the fascia, and from the anterior and posterior fibular intermuscular septa : occasionally also by a few fibres from the lateral condyle of the tibia. Between its attachments to the head and body of the fibula there is a gap through which the common peronæal nerve passes to the front of the leg. It ends in a long tendon, which runs behind the lateral malleolus, in a groove common to it and the tendon of the *Peronæus brevis*, behind which it lies ; the groove is converted into a canal by the superior peronæal retinaculum, and the tendons in it are contained in a common mucous sheath. The tendon then extends obliquely forwards across the lateral side of the calcaneus, below the trochlear process and the tendon of the *Peronæus brevis*, and under cover of the inferior peronæal retinaculum ; it crosses the lateral side of the cuboid bone, and then runs on the under surface of that bone in a groove which is converted into a canal by the long plantar ligament. It then crosses the sole of the foot obliquely, and is inserted into the lateral side of the base of the first metatarsal bone and the lateral side of the first cuneiform bone ; occasionally it sends a slip to the base of the second metatarsal bone. The tendon changes its direction at two points : first, below the lateral malleolus ; secondly, on the cuboid bone ; in both of these situations it is thickened, and, in the latter, a sesamoid fibrocartilage (sometimes a bone) is usually developed in its substance.

The *Peronæus brevis* arises from the lower two-thirds of the lateral surface of the body of the fibula, in front of the *Peronæus longus* ; and from the anterior and posterior fibular intermuscular septa. The fibres pass vertically downwards, and end in a tendon which runs behind the lateral malleolus along with but in front of that of the *Peronæus longus*, the two tendons being enclosed in the same compartment, and lubricated by a common mucous sheath. It then runs forwards on the lateral side of the calcaneus, above the trochlear process and the tendon of the *Peronæus longus*, and is inserted into the tuberosity at the base of the fifth metatarsal bone, on its lateral side.

On the lateral surface of the calcaneus the tendons of the *Peronæi longus* and *brevis* occupy separate osseo-aponeurotic canals formed by the calcaneus and the inferior peronæal reticulum ; each tendon is enveloped by a forward prolongation of the common mucous sheath.

Nerves.—The *Peronæi longus* and *brevis* are supplied by the fourth and fifth lumbar and first sacral nerves through the superficial peronæal nerve.

Actions.—The *Peronæi longus* and *brevis* extend the foot upon the leg, in conjunction with the *Tibialis posterior*, antagonising the *Tibialis anterior* and *Peronæus tertius*. The *Peronæus longus* also everts the foot, and from the oblique direction of its tendon across the sole is an important agent in the maintenance of the transverse arch of the foot. Taking their fixed points below, the *Peronæi* serve to steady the leg upon the foot. This is especially the case in standing upon one leg, when the tendency of the superincumbent weight is to throw the leg medialwards : the *Peronæus longus* overcomes this tendency by drawing on the lateral side of the leg.

Applied Anatomy.—The student should now consider the positions of the tendons of the various muscles of the leg, their relations with the ankle-joint and surrounding blood vessels, and especially their actions upon the foot, as their rigidity and contraction give rise to one or other of the kinds of deformity known as *club foot*. The most simple and common deformity, and one that is rarely, if ever, congenital, is *talipes equinus*, the heel being raised by the rigidity and contraction of the *Gastrocnemius* so that the patient walks upon the ball of the foot. In *talipes varus*, the foot is forcibly adducted and the medial side of the sole raised, sometimes to a right angle with the ground, by the action of the *Tibiales anterior* and *posterior*. In *talipes valgus*, the lateral edge of the foot is raised by the *Peronæi*, and the patient walks on the medial side of the foot. In *talipes calcaneus* the toes are raised by the *Extensor* muscles, the heel is depressed and the patient walks upon it. Other varieties of deformity are met with, as *talipes equinovarus*, *equinovalgus*,

and *calcaneovalgus*, names which sufficiently indicate their nature. Of these, talipes equinovarus is the most common congenital form; the heel is raised by the tendo calcaneus, the medial border of the foot drawn upwards by the Tibialis anterior, the anterior two-thirds twisted medialwards by the Tibialis posterior, and the arch increased by the contraction of the plantar aponeurosis, so that the patient walks on the middle of the lateral border of the foot. Each of these deformities may sometimes be successfully relieved by division of the opposing tendons and fascia; by this means the foot regains its proper position, and the tendons heal by the organisation of lymph thrown out between the divided ends. The operation is easily performed by putting the contracted tendon upon the stretch, and dividing it by means of a narrow, sharp-pointed knife inserted beneath it.

Rupture of a few of the fibres of the Gastrocnemius, or rupture of the Plantaris tendon, not uncommonly occurs, especially in men somewhat advanced in life, from some sudden exertion, and frequently occurs during the game of lawn-tennis, and is hence known as 'lawn-tennis leg.' The accident is accompanied by a sudden pain, and produces a sensation as if the individual had been struck a violent blow on the part. The tendo calcaneus is also sometimes ruptured. It is stated that John Hunter ruptured his tendo calcaneus while dancing, at the age of forty. The bursa between the tendo calcaneus and the posterior surface of the calcaneus sometimes becomes inflamed, especially in pedestrians and 'long-distance' walkers. It causes great and disabling pain, and entirely prevents the sufferer from continuing his walk.

FASCIA ROUND THE ANKLE

Fibrous bands, thickened portions of fascia, bind down the tendons in front of and behind the ankle in their passage to the foot. They comprise the transverse crural, cruciate crural, and lacinate ligaments, and the superior and inferior peronæal retinacula.

The **transverse crural ligament** (upper part of anterior annular ligament) (figs. 578, 581) binds down the tendons of the Tibialis anterior, Extensor hallucis longus, Extensor digitorum longus and Peronæus tertius as they descend on the front of the tibia and fibula; the anterior tibial vessels and the deep peronæal nerve also pass under cover of it. It is attached laterally to the lower end of the fibula, and medially to the tibia; above, it is continuous with the fascia of the leg.

The **cruciate crural ligament** (lower part of anterior annular ligament) (figs. 578, 581) is a Y-shaped band placed in front of the ankle-joint. The stem of the Y is attached to the upper surface of the calcaneus, in front of the sulcus calcanei; it is directed medialwards in front of the tendons of the Peronæus tertius and Extensor digitorum longus and divides into two limbs. One limb is directed upwards and medialwards, to be attached to the tibial malleolus, passing over the Extensor hallucis longus and the anterior tibial vessels and deep peronæal nerve, but enclosing the Tibialis anterior by a splitting of its fibres. The other limb extends downwards and medialwards, to be attached to the border of the plantar aponeurosis; it crosses the tendons of the Extensor hallucis longus and Tibialis anterior, and the arteria dorsalis pedis and the terminal branches of the deep peronæal nerve.

The **lacinate ligament** (internal annular ligament) extends from the tibial malleolus above to the margin of the calcaneus below; its upper border is continuous with the deep fascia of the leg, its lower with the plantar aponeurosis and the fibres of origin of the Abductor hallucis muscle. It converts a series of bony grooves in this situation into canals for the passage of the tendons of the flexor muscles into the sole of the foot and also affords protection to the posterior tibial vessels and tibial nerve as they enter the sole of the foot. From the medial to the lateral side, these structures lie in the following order: tendon of the Tibialis posterior, tendon of the Flexor digitorum longus, posterior tibial vessels and tibial nerve, and tendon of the Flexor hallucis longus.

The **peronæal retinacula** are fibrous bands which retain the tendons of the Peronæi longus and brevis in position as they cross the lateral side of the ankle. The **superior retinaculum** (external annular ligament) is attached above to the lateral malleolus and below to the lateral surface of the calcaneus. The **inferior retinaculum** is continuous in front with the cruciate crural ligament; behind it is attached to the lateral surface of the calcaneus; some of its

fibres are fixed to the trochlear process of the calcaneus, forming a septum between the tendons of the Peronæi longus and brevis.

The mucous sheaths of the tendons round the ankle.—The tendons crossing the ankle-joint are enclosed in mucous sheaths which have an almost

FIG. 581.—The mucous sheaths of the tendons round the ankle. Lateral aspect.

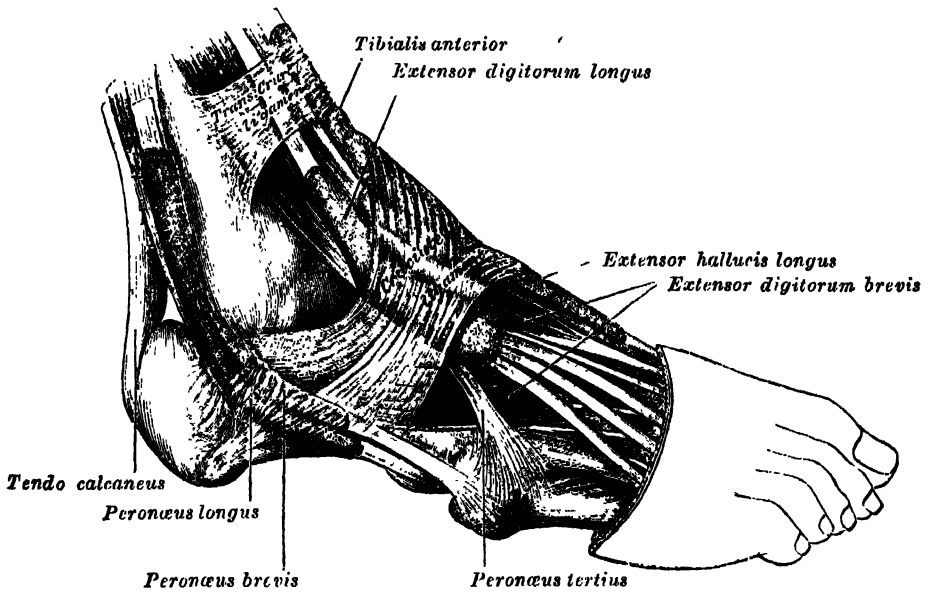
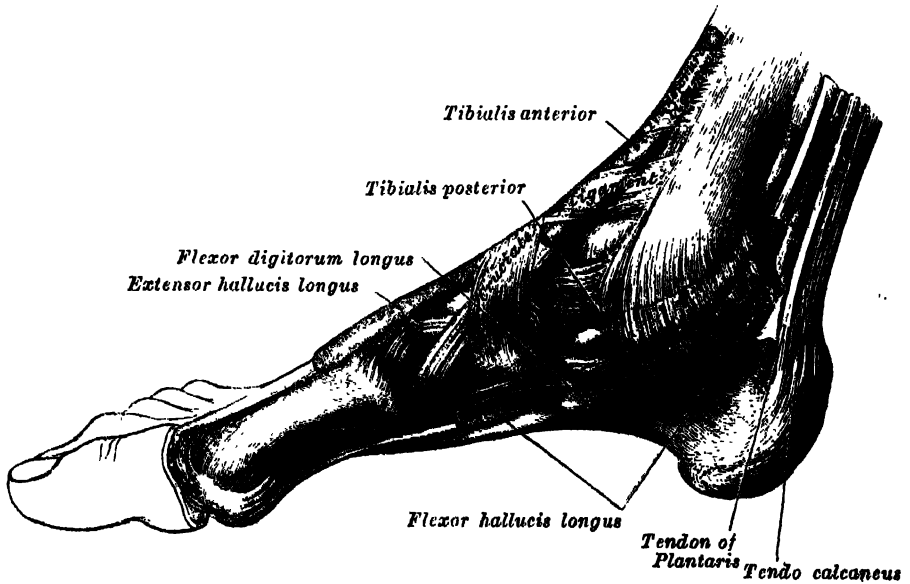


FIG. 582.—The mucous sheaths of the tendons round the ankle. Medial aspect.



uniform length of about 8 cm. each. On the *front* of the ankle (fig. 581) the sheath for the Tibialis anterior extends from the upper margin of the transverse crural ligament to the interval between the diverging limbs of the cruciate ligament; those for the Extensor digitorum longus and Extensor hallucis longus reach upwards to just above the level of the malleoli, the former being the higher. The sheath of the Extensor hallucis longus is prolonged on to

the base of the first metatarsal bone, while that of the Extensor digitorum longus reaches only to the level of the base of the fifth metatarsal bone. On the *medial side* of the ankle (fig. 582) the sheath for the Tibialis posterior extends for about 4 cm. above the malleolus; below, it ends just short of the insertion of the tendon into the tuberosity of the navicular bone. The sheath for Flexor hallucis longus reaches up to the level of the malleolus, while that for the Flexor digitorum longus is slightly higher; the former is continued to the base of the first metatarsal bone, but the latter ends opposite the navicular bone.

On the *lateral side* of the ankle (fig. 581) a sheath, which is single for the greater part of its extent, encloses the Peronæi longus and brevis. It extends upwards for about 4 cm. above the tip of the malleolus and downwards and forwards for about the same distance.

IV. MUSCLES OF THE FOOT

1. DORSAL MUSCLE OF THE FOOT

Extensor digitorum brevis

The **fascia** on the dorsum of the foot (*fascia dorsalis pedis*) is a thin membranous layer, continuous above with the transverse and cruciate crural ligaments; on either side it blends with the plantar aponeurosis; anteriorly it forms a sheath for the tendons on the dorsum of the foot.

The **Extensor digitorum brevis** (figs. 578, 581) is a thin muscle, which arises from the forepart of the upper and lateral surface of the calcaneus, in front of the groove for the Peronæus brevis; from the lateral talocalcaneal ligament, and the stem of the cruciate crural ligament. It passes obliquely forwards and medialwards across the dorsum of the foot, and ends in four tendons. The medial part of the muscle is usually a more or less distinct slip ending in a tendon which crosses the dorsalis pedis artery and is inserted into the dorsal surface of the base of the first phalanx of the great toe; it is sometimes described as a separate muscle—the *Extensor hallucis brevis*. The other three tendons are inserted into the lateral sides of the tendons of the Extensor digitorum longus of the second, third, and fourth toes.

Nerves.—It is supplied by the deep peronæal nerve.

Actions.—The Extensor digitorum brevis extends the phalanges of the four toes into which it is inserted, but, in the great toe, acts only on the first phalanx.

2. PLANTAR MUSCLES OF THE FOOT

The **plantar aponeurosis** is of great strength, and consists of white fibres disposed, for the most part, longitudinally: it is divided into central, lateral, and medial portions.

The *central portion*, the thickest, is narrow behind, and attached to the medial process of the tuberosity of the calcaneus, posteriorly to the origin of the Flexor digitorum brevis; it becomes broader and thinner in front, and divides near the heads of the metatarsal bones into five processes, one for each of the toes. Each of these processes splits opposite the metatarsophalangeal articulation into two strata, superficial and deep. The superficial stratum is inserted into the skin of the transverse sulcus which separates the toes from the sole. The deep stratum divides into two slips which embrace the sides of the flexor tendons of the toes, and blend with the sheaths of the tendons, and with the transverse metatarsal ligament, thus forming a series of arches through which the tendons of the short and long flexors pass to the toes. Through the intervals between the five processes the digital vessels and nerves and the tendons of the Lumbricales are transmitted. At the point of division of the aponeurosis are numerous transverse fasciculi which bind the processes together, and connect them with the integument. The central portion of the plantar aponeurosis is continuous with the lateral and medial portions, and sends upwards into the foot, at the lines of junction, two vertical intermuscular

septa, which separate the intermediate from the lateral and medial groups of plantar muscles; from these vertical septa thinner transverse septa are derived which separate the different layers of muscles in this region. The upper surface of the central part of the aponeurosis gives origin behind to the *Flexor digitorum brevis*.

The *lateral portion* covers the under surface of the *Abductor digiti quinti*; it is thin in front and thick behind, where it forms a strong band between the lateral process of the tuberosity of the calcaneus and the base of the fifth metatarsal bone; it is continuous medially with the central portion, and laterally with the fascia dorsalis pedis.

FIG. 583.—Muscles of the sole of the foot. First layer.



The *medial portion* is thin, and covers the under surface of the *Abductor hallucis*; it is attached behind to the lacinate ligament, and is continuous medially with the fascia dorsalis pedis, and laterally with the central portion of the plantar aponeurosis.

The muscles in the plantar region of the foot may be divided into medial, lateral and intermediate groups; but for descriptive purposes it is more convenient to divide them into four layers, in the order in which they are successively exposed in dissecting this region.

First Layer (fig. 583)

Abductor hallucis.
Flexor digitorum brevis.
Abductor digiti quinti.

The *Abductor hallucis* lies along the medial border of the foot and covers the origins of the plantar vessels and nerves. It arises from the medial process of the tuberosity of the calcaneus, the lacinate ligament, the plantar aponeurosis, and the intermuscular septum between it and the *Flexor digitorum brevis*. The fibres end in a tendon which is inserted, together with the medial tendon of the *Flexor hallucis brevis*, into the medial side of the base of the first phalanx of the great toe.

The *Flexor digitorum brevis* lies immediately above the central part of the plantar aponeurosis. Its deep surface is separated from the lateral plantar vessels and nerves by a thin layer of fascia. It arises by a narrow tendon, from the medial process of the tuberosity of the calcaneus, the central part of

the plantar aponeurosis, and the intermuscular septa between it and the adjacent muscles. It divides into four tendons, one for each of the four lesser toes. Opposite the bases of the first phalanges, each tendon divides into two slips, to allow of the passage of the corresponding tendon of the *Flexor digitorum longus*; the two slips then unite and form a grooved channel for the reception of the accompanying long flexor tendon. The tendon divides again and is inserted into the sides of the second phalanx about its middle. The mode of division of the tendons of the *Flexor digitorum brevis*, and of their insertion into the phalanges, is analogous to that of the tendons of the *Flexor digitorum sublimis* in the hand.

Fibrous sheaths of the flexor tendons.—The terminal portions of the tendons of the long and short flexor muscles are contained in osseo-aponeurotic canals similar in their arrangement to those in the fingers. These canals are bounded above by the phalanges, and below by fibrous bands, which arch across the tendons, and are attached on either side to the margins of the phalanges. Opposite the bodies of the proximal and second phalanges the fibrous bands (*vaginal ligaments*) are strong, and the fibres are transverse; but opposite the joints they are much thinner, and the fibres are directed obliquely. Each canal contains a mucous sheath, which is reflected on the contained tendons; within this sheath are *vincula tendinea* arranged similarly to those of the fingers.

The **Abductor digiti quinti** lies along the lateral border of the foot, and its medial margin is in relation with the lateral plantar vessels and nerve. It arises from the lateral and medial processes of the tuberosity of the calcaneus, the under surface of the bone between the processes, the plantar aponeurosis, and the intermuscular septum between it and the *Flexor digitorum brevis*. Its tendon glides over a smooth facet on the under surface of the base of the fifth metatarsal bone and is inserted, with the *Flexor digiti quinti brevis*, into the lateral side of the base of the first phalanx of the fifth toe.

Second Layer (fig. 584)

Quadratus plantæ.

Lumbricales.

The **Quadratus plantæ** (*Flexor accessorius*) arises by two heads, which are separated from each other by the long plantar ligament: the medial, the larger, head is muscular, and is attached to the medial concave surface of the calcaneus, below the groove for the tendon of the *Flexor hallucis longus*; the lateral head, flat and tendinous, arises from the calcaneus in front of the lateral process of its tuberosity, and from the long plantar ligament. The two portions join at an acute angle, and end in a flattened band which is inserted into the surfaces and lateral margin of the tendon of the *Flexor digitorum longus*, forming a kind of groove in which the tendon is lodged. It usually sends slips to those tendons of the *Flexor digitorum longus* which pass to the second, third, and fourth toes.

The **Lumbricales** are four small muscles, accessory to the tendons of the *Flexor digitorum longus*, and numbered from the medial side of the foot; they arise from these tendons, as far back as their angles of separation, each springing from two tendons, except the first, which arises only from the medial border of the first tendon of the *Flexor digitorum longus*. The muscles end in tendons, which pass forwards on the medial sides of the four lesser toes, and are inserted into the expansions of the tendons of the *Extensor digitorum longus* on the dorsal surfaces of the first phalanges.

Third Layer (fig. 585)

Flexor hallucis brevis.

Adductor hallucis.

Flexor digiti quinti brevis.

The **Flexor hallucis brevis** arises by a pointed tendinous process from the medial part of the under surface of the cuboid bone, the contiguous portion of the third cuneiform bone, and the prolongation of the tendon of the *Tibialis posterior* which is attached to that bone. It divides into two portions, and the tendons of these are inserted into the medial and lateral sides of the base of the first phalanx of the great toe, a sesamoid bone being present in each tendon at its insertion. The medial portion is blended with the *Abductor hallucis* previous to its insertion; the lateral with the *Adductor hallucis*; the tendon of the *Flexor hallucis longus* lies in a groove between them; the lateral portion is sometimes described as the *first plantar interosseous* muscle.

The **Adductor hallucis** arises by two heads—oblique and transverse. The *oblique head* springs from the bases of the second, third, and fourth metatarsal bones, and the sheath of the tendon of the *Peroneus longus*, and is inserted, together with the lateral portion of the *Flexor hallucis brevis*, into the lateral side of the base of the first phalanx of the great toe. The *transverse*

head (*Transversus pedis*), a narrow, flat fasciculus, arises from the plantar metatarsophalangeal ligaments of the third, fourth, and fifth toes (sometimes only from the third and fourth), and from the transverse ligament of the metatarsus. It is inserted into the lateral side of the base of the first phalanx of the great toe, its tendon of insertion blending with that of the oblique head.

FIG. 584.—Muscles of the sole of the foot. Second layer.

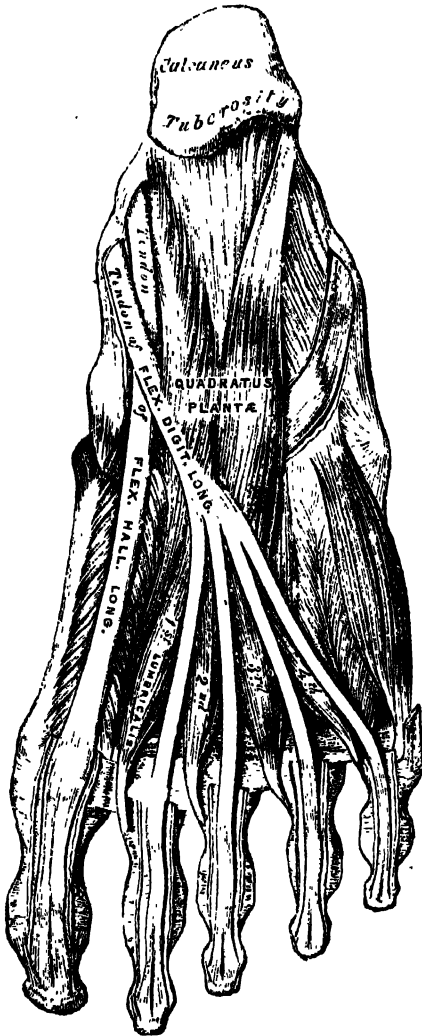


FIG. 585.—Muscles of the sole of the foot. Third layer.



The *Flexor digiti quinti brevis* arises from the base of the fifth metatarsal bone, and the sheath of the *Peronæus longus*; its tendon is inserted into the lateral side of the base of the first phalanx of the fifth toe. Occasionally a few of the deeper fibres are inserted into the lateral part of the distal half of the fifth metatarsal bone; these are described by some as a distinct muscle, the *Opponens digiti quinti*.

Fourth Layer.

Interossei.

The *Interossei* in the foot are similar to those in the hand, but are grouped on either side of the middle line of the *second* digit, instead of that of the *third*. They consist of a dorsal and a plantar set.

The **Interossei dorsales** (fig. 586), four in number, are situated between the metatarsal bones. They are bipennate muscles, each arising by two heads from the adjacent sides of the metatarsal bones between which it is placed; their tendons are inserted into the bases of the first phalanges, and into the aponeuroses of the tendons of the *Extensor digitorum longus*. The first is inserted into the medial side of the second toe; the other three into the lateral sides of the second, third, and fourth toes. In the angular interval between the heads of each of the three lateral muscles, one of the perforating arteries passes to the dorsum of the foot; through the space between the heads of the first muscle the deep plantar branch of the *dorsalis pedis* artery enters the sole of the foot.

FIG. 586.—The *Interossei dorsales*.
Left foot.

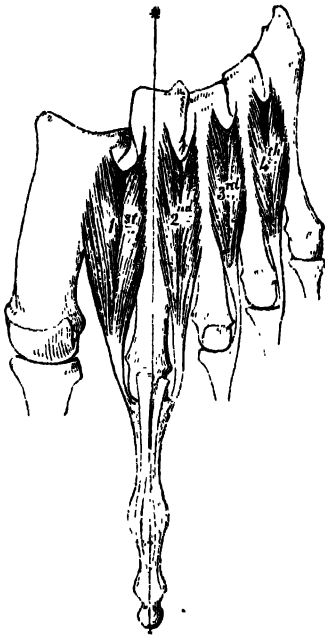
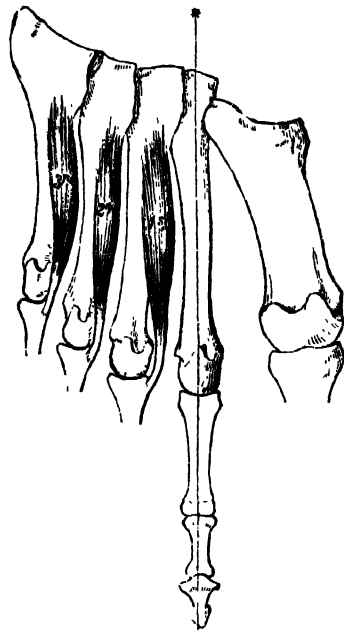


FIG. 587.—The *Interossei plantares*.
Left foot.



The **Interossei plantares** (fig. 587), three in number, lie beneath rather than between the metatarsal bones, and each is connected with but one metatarsal bone. They arise from the bases and medial sides of the bodies of the third, fourth, and fifth metatarsal bones, and are inserted into the medial sides of the bases of the first phalanges of the same toes, and into the aponeuroses of the tendons of the *Extensor digitorum longus*.

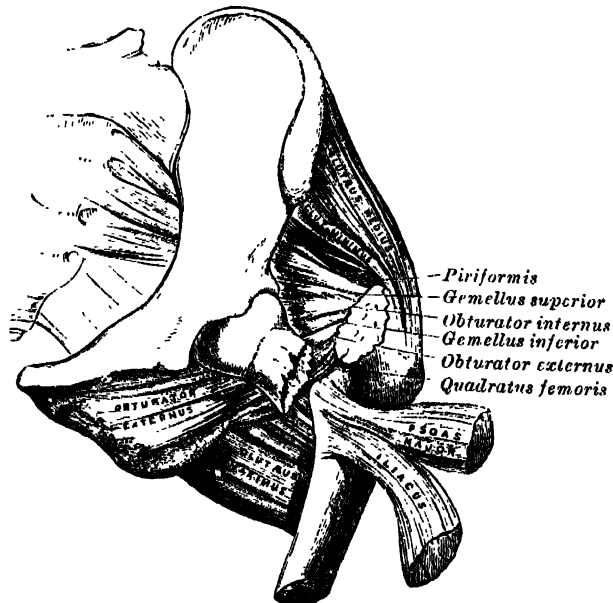
Nerves.—The *Flexor digitorum brevis*, the *Flexor hallucis brevis*, the *Abductor hallucis*, and the first *Lumbricalis* are supplied by the medial plantar nerve; all the other muscles in the sole of the foot by the lateral plantar. The first *Interosseus dorsalis* frequently receives an extra filament from the medial branch of the deep peroneal nerve on the dorsum of the foot, and the second *Interosseus dorsalis* a twig from the lateral branch of the same nerve.

Actions.—The plantar muscles of the foot act upon the toes, and may be grouped as abductors, adductors, flexors, and extensors. The *abductors* are the *Interossei dorsales*, the *Abductor hallucis*, and the *Abductor digiti quinti*. The *Interossei dorsales* are abductors from an imaginary line passing through the axis of the second toe, so that the first muscle draws the second toe medialwards, the second muscle draws the same toe lateralwards, and the third and fourth draw the third and fourth toes lateralwards. Like the *Interossei* in the hand, they assist in flexing the first and extending the second and third phalanges. The *Abductor hallucis* abducts the great toe from the second, and also flexes its proximal phalanx. In the same way the action of the *Abductor digiti quinti* is twofold, as an abductor

MYOLOGY

of this toe from the fourth, and a flexor of its proximal phalanx. The *adductors* are the *Interossei plantares* and the *Adductor hallucis*. The *Interossei plantares* adduct the third, fourth, and fifth toes towards the imaginary line passing through the second toe, and, by means of their insertions into the aponeuroses of the *Extensor tendons*, assist in flexing the proximal phalanges and extending the middle and terminal phalanges. The oblique head of the *Adductor hallucis* is chiefly concerned in adducting the great toe, but it also assists in flexing this toe; the transverse head approximates all the toes and thus increases the curve of the transverse arch of the metatarsus. The *flexors* are the *Flexor digitorum brevis*, the *Quadratus plantæ*, the *Flexor hallucis brevis*, the *Flexor digiti quinti brevis*, and the *Lumbricales*. The *Flexor digitorum brevis* flexes the second phalanges upon the first, and, continuing its action, flexes the first phalanges also, and brings the toes together. The *Quadratus plantæ* assists the *Flexor digitorum longus* and converts the oblique

FIG. 588.—Fracture of the neck of the femur within the articular capsule.



pull of the tendons of that muscle into a direct backward pull upon the toes. The *Flexor digiti quinti brevis* flexes the little toe and draws its metatarsal bone downwards and medialwards. The *Lumbricales*, like the corresponding muscles in the hand, assist in flexing the proximal phalanges, and, by their insertions into the tendons of the *Extensor digitorum longus*, aid that muscle in extending the middle and terminal phalanges.

Applied Anatomy.—The student should now consider the effects produced by the action of the various muscles in fractures of the bones of the lower extremity. The more common forms of fracture are selected for illustration and description.

In fracture of the neck of the femur inside the articular capsule (fig. 588), the characteristic signs are slight shortening of the limb, and eversion of the foot, neither of which may appear until some time after the injury. The eversion is caused by the weight of the limb rotating it outwards. The shortening is produced by the contraction of all the muscles about the joint.

In fracture of the femur just below the trochanters (fig. 589), the upper fragment is tilted forwards almost at right angles with the pelvis, by the *Psoas major* and *Iliacus*; and, at the same time, everted and drawn laterally by the external rotator muscles and *Glutæi*, causing a marked prominence at the upper and lateral side of the thigh, and much pain from the bruising and laceration of the muscles. The limb is shortened, because the lower fragment is drawn upwards by the *Rectus femoris* in front, and the *Biceps femoris*, *Semimembranosus*, and *Semitendinosus* behind; it is, at the same time, everted. This

fracture may be reduced by relaxation of all the muscles involved, to effect which the limb should be put up with the thigh flexed on the pelvis and the leg on the thigh.

FIG. 589.—Fracture of the femur below the trochanters.



FIG. 591.—Fracture of the patella.



FIG. 592.—Oblique fracture of the body of the tibia.

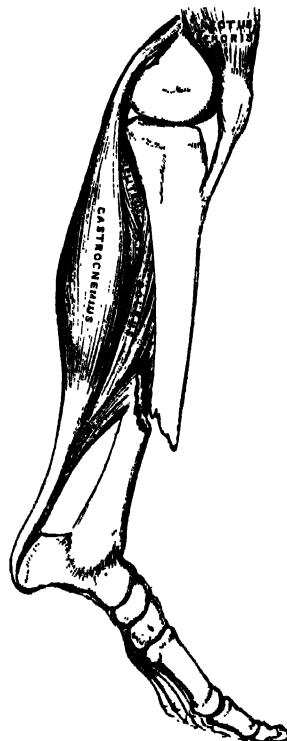
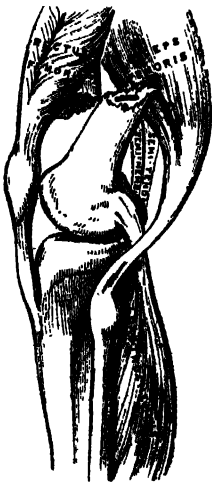


FIG. 590.—Fracture of the femur above the condyles.



Oblique fracture of the femur *immediately above the condyles* (fig. 590) is a formidable injury, and attended with considerable displacement. On examination of the limb,

the lower fragment may be felt deep in the popliteal fossa, being drawn backwards by the Gastrocnemius, and upwards by the hamstrings and Rectus femoris. The pointed end of the upper fragment is drawn medialwards by the Pectineus and Adductors, and tilted forwards by the Psoas major and Iliacus, piercing the Rectus, and occasionally the integument. Relaxation of these muscles, and direct approximation of the broken fragments, are effected by traction with the limb fully flexed. The greatest care is requisite in keeping the pointed extremity of the upper fragment in proper position; otherwise, after union of the fracture, the power of extension of the limb is partially destroyed, the Rectus femoris being held down by the fractured end of the bone.

In transverse fracture of the *patella* (fig. 591) the fragments are separated by the action of the Quadriceps femoris and by the effusion which takes place into the joint; the extent of separation of the two fragments depending upon the degree of laceration of the ligamentous structures around the bone.

Oblique fracture of the *body of the tibia* (fig. 592). If the fracture takes place obliquely from above, downwards and forwards, the fragments ride over one another, the lower fragment being drawn backwards and upwards by the powerful action of the muscles of the calf; the pointed extremity of the upper fragment projects forwards immediately beneath the integument, often protruding through it, and rendering the fracture compound. If the direction of the fracture is the reverse of that shown in the figure, the pointed extremity of the lower fragment projects forwards, rising up on the lower end of the upper one. By bending the knee, which relaxes the opposing muscles, and making extension from the ankle and counter-extension at the knee, the fragments may be brought into apposition. It is sometimes necessary, however, in compound fracture to remove a portion of the projecting bone with the saw before complete adaptation can be effected.

Fracture of the *fibula with dislocation of the foot lateralwards*, commonly known as 'Pott's fracture,' is one of the most frequent injuries in the region of the ankle-joint. The fibula is fractured about 7 or 8 cm. above the ankle; in addition to this the medial malleolus is broken off, or the deltoid ligament torn through, and the talus displaced from the corresponding surface of the tibia. The foot is markedly everted, and the sharp edge of the upper end of the fractured malleolus presses strongly against the skin; at the same time, the heel is drawn up by the muscles of the calf. This injury can generally be reduced by flexing the leg at right angles with the thigh, which relaxes all the opposing muscles, and by making extension from the ankle and counter-extension at the knee. There is later a great tendency for the foot to fall backwards at the ankle-joint, and constant supervision is required to counteract this.

ANGIOLOGY

THE vascular system is divided for descriptive purposes into (a) the *blood vascular system*, comprising the heart and blood-vessels through which the blood circulates ; * and (b) the *lymph vascular system*, consisting of lymph glands and lymphatic vessels, through which a colourless fluid, the lymph, circulates. The two systems communicate with each other and are intimately associated developmentally.

The heart, the central organ of the blood vascular system, is a hollow muscle ; by its contraction the blood is pumped to all parts of the body through a complicated series of tubes, termed *arteries*. The arteries undergo enormous ramification in their course throughout the body, and end in minute vessels, called *arterioles*, which open into a close-meshed network of microscopic vessels, termed *capillaries*. After the blood has passed through the capillaries it is collected into a series of vessels, called *veins* ; these unite with one another, and ultimately two large veins, named the superior and inferior venæ cavæ, are formed which return the blood to the heart. The passage of the blood through the heart and blood-vessels is termed the *circulation* of the blood, of which the following is an outline.

The heart is divided into right and left halves, and each half is subdivided into two cavities, an atrium and a ventricle, which communicate freely with one another ; the atria are receiving chambers and the ventricles distributing ones. The right atrium and right ventricle form the right half, and the left atrium and left ventricle the left half of the heart ; the right half contains venous or impure blood ; the left, arterial or pure blood. From the cavity of the left ventricle the pure blood is carried into a large artery, the aorta, through the numerous branches of which it is distributed to all parts of the body, with the exception of the lungs. As the blood traverses the capillaries of the body it gives up to the tissues the materials necessary for their growth and nourishment, and receives from the tissues the waste products resulting from their metabolism. In doing so it is changed from arterial into venous blood, which is collected by the veins and returned by them to the right atrium of the heart. From this cavity the venous blood passes into the right ventricle, and from it is conveyed through the pulmonary arteries to the lungs, where it becomes arterialised, and is carried thence to the left atrium by the pulmonary veins. From the left atrium it passes into the left ventricle, from which the cycle once more begins.

The course of the blood from the left ventricle through the body generally to the right side of the heart constitutes the greater or *systemic* circulation, while its passage from the right ventricle through the lungs to the left side of the heart is termed the lesser or *pulmonary* circulation.

It is necessary, however, to state that the blood which circulates through the spleen, pancreas, stomach, small intestine, and the greater part of the large intestine is not returned directly from these organs to the heart, but is conveyed by the *portal vein* to the liver. In the liver this vein divides like an artery, and ultimately ends in capillary-like vessels (*sinusoids*), from which the rootlets of the *hepatic veins* arise ; the hepatic veins carry the blood into the inferior vena cava, whence it is conveyed to the right atrium. From this it will be understood that the blood supplied to the above-named viscera passes through two sets of vessels before reaching the inferior vena cava : (1) the

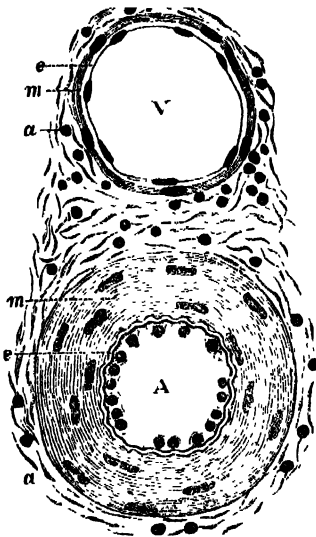
*The blood is described on pp. 26 to 29.

capillaries in the spleen, pancreas, stomach, &c., draining into the portal vein and (2) the sinusoids in the liver, draining into the hepatic veins.

Structure of arteries (fig. 593).—The wall of an artery consists of three coats, an internal or *tunica intima*, a middle or *tunica media*, and an external or *tunica adventitia*. The external coat is tougher than the other two, which are ruptured when a ligature is tied round the vessel, and, in virtue of their elasticity, become retracted from the site of the ligature.

The *tunica intima* consists of (a) an internal layer of flattened cells, (b), beneath these, a small quantity of loose connective tissue, and (c) an elastic lamina. The flattened or endothelial cells are fusiform in shape with the long axis of each in the long axis of the blood-vessel. Each cell possesses a nucleus, and is attached to adjacent cells by cement-substance which reduces silver nitrate. The connective

FIG. 593.—Transverse section through a small artery and vein of the mucous membrane of the epiglottis of a child. $\times 350$. (Klein and Noble Smith.)



A. Artery, showing the nucleated endothelium, *e*, which lines it; the vessel being contracted, the endothelial cells appear very thick. Outside the endothelium is the wavy elastic lamina. The chief part of the wall of the vessel is occupied by the circular muscular coat *m*: the rod-shaped nuclei of the muscle-cells are well seen; *a*, part of the adventitia which gradually merges into the surrounding connective tissue. V. Vein showing a thin endothelial membrane, *e*, raised accidentally from the intima, which on account of its delicacy is seen as a mere line on the media *m*. This latter is composed of a few smooth muscle-cells. *a*. The adventitia, similar in structure to that of an artery.

tissue layer is very thin, and contains branched cells, and, in the larger arteries, fine elastic fibres. The elastic lamina is built up of longitudinally arranged elastic fibres fused together, and is usually fenestrated, having round or oval apertures at irregular intervals. In a transverse section of an artery it appears as a characteristic wavy line, owing to the contracted condition of the empty vessel.

The *tunica media*, in the smaller and medium-sized arteries, consists principally of smooth muscular fibres arranged circularly round the vessel; the fibres have well-marked, rod-shaped nuclei. In the smallest arteries the middle coat is entirely composed of smooth muscular fibres (fig. 594). In medium-sized arteries (fig. 595) there are in addition elastic fibres and fine elastic membranes lying between the layers of muscular fibres. In the larger arteries, as the iliac and carotid, the proportion of elastic tissue is greatly increased, and in the aorta relatively thick elastic laminae form the greater part of the thickness of the middle coat.

The *tunica adventitia* consists mainly of fine and closely felted bundles of white connective tissue; in all but the smallest arteries it contains some elastic fibres. The elastic tissue is most abundant next the tunica media, and it is sometimes described as forming here, between the adventitia and media, a special layer, the *tunica elastica externa* of Henle; this layer is most marked in arteries of medium size. In the largest vessels the external coat is relatively thin, but in small

arteries it is of greater proportionate thickness. In the smaller arteries it consists of a single layer of white connective tissue and elastic fibres; in the smallest arteries the elastic fibres are wanting, and the connective tissue, of which the coat is composed, becomes more homogeneous the nearer it approaches the capillaries, and is gradually reduced to a thin membranous envelope, which finally disappears.

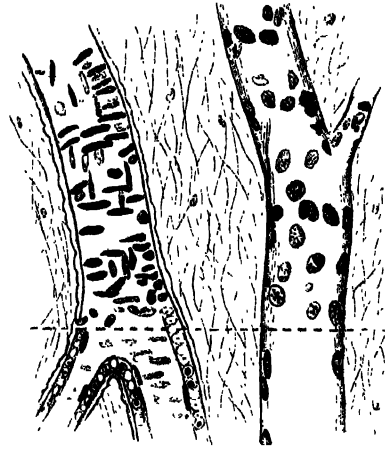
Some arteries have extremely thin walls in proportion to their size; this is especially the case in those situated within the cranium and vertebral canal, and depends on the thinness of the external and middle coats.

The arteries, in their distribution throughout the body, are enclosed in thin fibro-areolar investments, which form their *sheaths*. The vessel is loosely connected with its sheath by delicate areolar tissue; and the sheath usually encloses the accompanying veins, and sometimes a nerve. Some arteries, as those in the cranium, are devoid of sheaths.

The larger arteries are supplied with blood-vessels. These nutrient vessels, called the *vasa vasorum*, arise from branches of the artery itself, or of a neighbouring vessel, at some considerable distance from the points at which they are distributed; they ramify in the loose areolar tissue connecting the artery with its sheath, and are distributed to the external coat; in man they do not penetrate the other coats; but in some of the larger mammals a few vessels have been traced into the middle coat. Minute veins return the blood from these vessels; they empty themselves into the vein or veins accompanying the artery. Lymphatic vessels are also present in the outer coat.

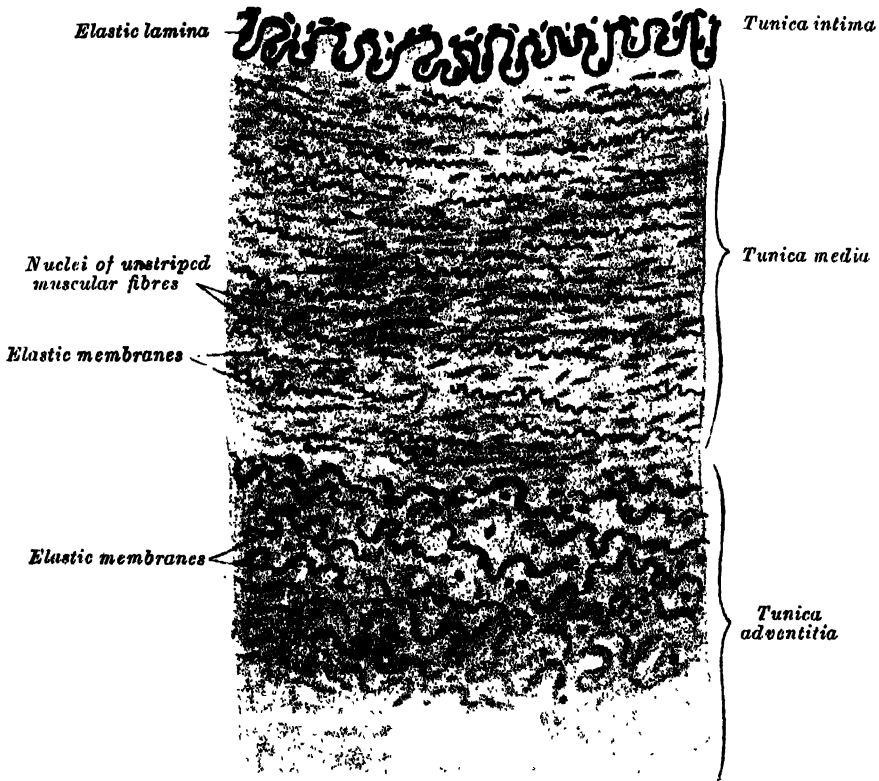
Arteries are also supplied with nerves, which form intricate plexuses upon the surfaces of the larger trunks, and run along the smaller arteries as single filaments, or bundles of filaments. Most of the nerve-fibres are non-medullated, and are derived from the sympathetic system, but some are medullated. The non-medullated fibres are, for the most part, efferent, and have their terminations in the middle coat. The medullated fibres are believed to be afferent and are distributed to the outer and inner coats. Pacinian corpuscles are occasionally found in the outer coat of the aorta.

FIG. 594.—Small artery and vein, from pia mater of sheep. $\times 250$.



Surface view above the interrupted line; longitudinal section below. Artery in red; vein in blue.

FIG. 595.—Transverse section of femoral artery of dog. $\times 250$.



The capillaries.—The smaller arterial branches (excepting those of the cavernous structure of the sexual organs, of the splenic pulp, and of the placenta) subdivide,

giving rise to minute vessels termed capillaries. These are interposed between the smallest branches of the arteries and the commencing veins, constituting a network, the branches of which maintain the same diameter throughout; the meshes of the network are more uniform in shape and size than those formed by the anastomoses of the small arteries and veins.

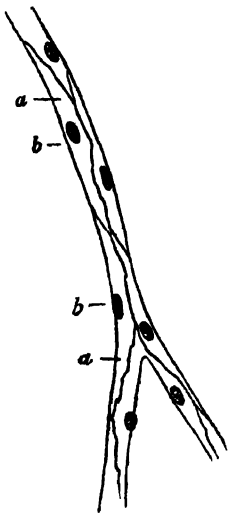
The *diameters* of the capillaries vary in the different tissues of the body, the usual size being about $8\ \mu$. The smallest are those of the brain and the mucous membrane of the intestines; and the largest those of the skin and the marrow of bone, where they are stated to be as large as $20\ \mu$ in diameter.

The *form* of the capillary net varies in the different tissues, the meshes being generally rounded or elongated. Rounded meshes are most common, and prevail where there is a dense network, as in the lungs, in most glands and mucous membranes, and in the cutis; the meshes are not of an absolutely circular outline, but more or less angular. Elongated meshes are observed in the muscles and nerves, the meshes resembling parallelograms in form, the long axis of the mesh running parallel with the long axis of the muscle or nerve. Sometimes the capillaries have a looped arrangement; a single vessel projecting from the common network and returning after forming one or more loops, as in the papillæ of the tongue and skin.

The number of the capillaries and the size of the meshes determine the degree of vascularity of a part; the closest network and the smallest interspaces are found in the lungs and in the chorioid coat of the eye. As a general rule, the more active the function of the organ, the closer is its capillary net and the larger its supply of blood. Blood-vessels are few in number in tendons, in which very little organic change occurs after their formation.

Structure.—The wall of a capillary consists of flattened cells joined edge to edge by cement-substance, and continuous with the endothelial cells which line

FIG. 596.—Capillaries from the mesentery of a guinea-pig, after treatment with solution of nitrate of silver.



a. Cells. b. Their nuclei.

the arteries and veins. When stained with nitrate of silver the edges which bound the epithelial cells are brought into view (fig. 596). These cells are of large size and of an irregular polygonal or lanceolate shape, each containing an oval nucleus which may be displayed by carmine or hæmatoxylin. Between their edges, at various points of their meeting, roundish dark spots are sometimes seen, which have been described as stomata, though they are closed by intercellular substance. By some they are believed to be the situations through which the colourless corpuscles of the blood, when migrating from the blood-vessels, emerge; but this view is not universally accepted.

In developing capillaries, and in the capillaries of the glomeruli of the kidneys, the intestinal villi, and the chorioid coat of the eye, intercellular cement cannot be demonstrated, and the cells are believed to form a syncytium.

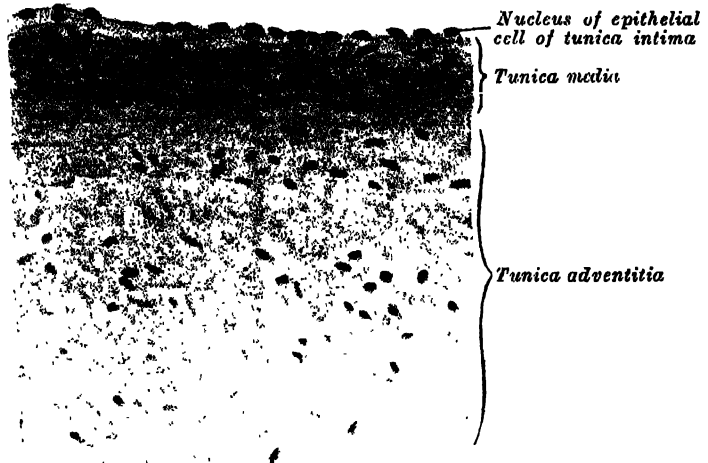
In many situations a delicate sheath or envelope of branched nucleated connective tissue cells is found around the simple capillary tube, particularly the larger ones; and in other places, especially in the glands, the capillaries are invested with retiform connective tissue.

Sinusoids.—In the heart, the liver, the supra-renal and parathyroid glands, the glomera carotica and glomus coccygeum, the smallest blood-vessels present various differences from true capillaries. They are wider, with an irregular lumen, and have no connective tissue covering, their endothelial cells being in direct contact with the cells of the organ. Moreover, they are either arterial or venous and not intermediate as are the true capillaries. These vessels have been called *sinusoids* by Minot. They are formed by columns of cells or trabeculae pushing their way into a large blood-vessel or blood-space and carrying its endothelium before them; at the same time the wall of the vessel or space grows out between the cell columns.

Structure of veins.—The walls of the veins, like those of the arteries, are composed of three coats—internal, middle, and external; and these are, with the necessary modifications, analogous to the coats of the arteries; the internal being the endothelial, the middle the muscular, and the external the connective tissue or areolar (fig. 593). The main difference between the veins and the arteries is in the comparative weakness of the middle coat in the former.

In the smallest veins the three coats are hardly to be distinguished (fig. 594). The endothelium is supported on a membrane separable into two layers, the outer of which is the thicker, and consists of a delicate, nucleated membrane (*tunica adventitia*), while the inner is composed of a network of longitudinal elastic fibres (*tunica media*). In the veins next above these in size (0.4 mm. in diameter), a connective tissue layer containing numerous smooth muscular fibres circularly disposed can be traced, forming the middle coat, while the elastic and connective tissue elements of the outer coat are more distinctly perceptible. In the middle-sized veins (fig. 597) the typical structure of these vessels becomes clear. The endothelium is of the same character as in the arteries, but its cells are shorter and

FIG. 597.—Transverse section of femoral vein of dog. $\times 250$. (Vein accompanying artery shown in fig. 595.) Elastic tissue is not differentiated in this preparation.



broad. It is supported by a connective tissue layer, consisting of a delicate network of branched cells, and external to this is a layer of elastic fibres disposed in the form of a network in place of the definite fenestrated membrane seen in arteries. This constitutes the *tunica intima*. The *tunica media* is composed of a thick layer of connective tissue with elastic fibres, intermixed, in some veins, with a layer of smooth muscular fibres arranged circularly. The white fibres are in considerable excess, and the elastic fibres are in much smaller proportion in the veins than in the arteries. The *tunica adventitia* consists, as in the arteries, of areolar tissue, with longitudinal elastic fibres. In the largest veins it is from two to five times thicker than the *tunica media*, and contains a large number of longitudinal muscular fibres. These are most distinct in the inferior vena cava, especially at the termination of this vein in the heart, in the trunks of the hepatic veins, in all the large trunks of the portal vein, and in the external iliac, renal, and azygos veins. In the inferior vena cava, renal and portal veins they extend through the whole thickness of the outer coat, but in the other veins mentioned a layer of connective and elastic tissue is found external to the muscular fibres. The large veins which open into the heart are covered for a short distance with a layer of striped muscular tissue continued on to them from the heart. Muscular tissue is wanting—(1) in the veins of the maternal part of the placenta; (2) in the venous sinuses of the dura mater and the veins of the pia mater; (3) in the veins of the retina; (4) in the veins of the spongy substance of bones; (5) in the venous spaces of the corpora cavernosa. The veins of the above-mentioned parts consist of an endothelial lining supported on one or more layers of areolar tissue.

Most veins are provided with *valves* which serve to prevent the reflux of the blood. Each valve is formed by a reduplication of the inner coat, strengthened by connective tissue and elastic fibres, and is covered on both surfaces by endothelium, the arrangement of which differs on the two surfaces. On the surface of the valve next the wall of the vein, the cells are arranged transversely; while on the other surface, over which the current of blood flows, the cells are arranged longitudinally in the direction of the current. Most commonly two such valves are found placed opposite one another, more especially in the smaller veins or in the larger trunks at the point where they are joined by smaller branches; occasionally there are three and sometimes only one. The valves are semilunar. They are attached by their convex edges to the wall of the vein; the concave margins are free, directed in the course of the venous current, and lie in close apposition with the wall of the vein as long as the current of blood takes its natural course; if, however, any regurgitation takes place, the valves become distended, their opposed edges are brought into contact, and the current is interrupted. The wall of the vein on the cardiac side of the attachment of each valve is expanded into a pouch or sinus, which gives to the vessel, when injected or distended with blood, a knotted appearance. The valves are very numerous in the veins of the extremities, especially in the veins of the lower extremities, these vessels having to conduct the blood against the force of gravity. They are absent in the very small veins, i.e. those less than 2 mm. in diameter, also in the *venæ cavæ*, hepatic, renal, uterine, and ovarian veins. A few valves are found in each testicular vein, and one also at its point of junction with the renal vein or inferior vena cava respectively. The cerebral and spinal veins, the veins of the cancellated tissue of bone, the pulmonary veins, and the umbilical vein and its branches, are destitute of valves. A few valves are occasionally found in the azygos and intercostal veins. Valves are present in the tributaries of the portal vein in the foetus and for a short time after birth; as a rule they soon atrophy and disappear, but sometimes they persist in a degenerate form.

The veins, like the arteries, are supplied with nutrient vessels, *vasa vasorum*. Nerves also are distributed to them in the same manner as to the arteries, but in much less abundance.

THE THORACIC CAVITY

The heart and lungs are situated in the thorax, the walls of which afford them protection. The heart lies between the two lungs, and is enclosed within a fibrous bag, the *pericardium*, while each lung is invested by a serous membrane, the *pleura*. The skeleton of the thorax, and the shape and boundaries of the cavity, have already been described (p. 190).

The cavity of the thorax.—The capacity of the thoracic cavity does not correspond with its apparent size externally, because (1) the space enclosed by the lower ribs is occupied by some of the abdominal viscera; and (2) the cavity extends for a short distance into the neck above the anterior parts of the first ribs. The size of the thoracic cavity is constantly varying during life with the movements of the ribs and Diaphragm, and with the degree of distention of the abdominal viscera.

The upper opening of the thorax.—The parts which pass through the upper opening of the thorax are, from before backwards in or near the middle line, the Sternohyoideus and Sternothyreoides muscles, the remains of the thymus, the inferior thyroid veins, the trachea, œsophagus, thoracic duct, and the Longus colli muscles; laterally the innominate veins, the innominate artery, the left common carotid and left subclavian arteries, the internal mammary arteries and the costocervical trunks, the vagus, cardiac, phrenic, and sympathetic nerves, the greater parts of the anterior divisions of the first thoracic nerves, and the left recurrent nerve. The apex of each lung, covered by the pleura, also projects through this aperture, a little above the level of the sternal end of the first rib.

The lower opening of the thorax is wider transversely than from before backwards. It slopes obliquely downwards and backwards, so that the thoracic cavity is much deeper behind than in front. The Diaphragm (see p. 452) closes the opening and forms the floor of the thorax. The floor is flatter at the centre than at the sides, and higher on the right side than on the

THE PERICARDIUM

51

left; in the dead body the right side reaches the level of the upper border of the fifth costal cartilage, while the left extends only to the corresponding part of the sixth costal cartilage. From the highest point on either side the floor slopes suddenly downwards to the costal and vertebral attachments of the Diaphragm; this slope is more marked behind than in front, so that only a narrow space is left between the Diaphragm and the posterior wall of the thorax.

THE PERICARDIUM

The pericardium (fig. 598) is a conical fibroserous sac, in which the heart and the roots of the great vessels are contained. It is placed in the mediastinal cavity, behind the sternum and the cartilages of the third, fourth, fifth, sixth, and seventh ribs of the left side, and in front of the thoracic vertebrae, from the fifth to the eighth inclusive.

In *front*, it is separated from the anterior wall of the thorax, in the greater part of its extent, by the lungs and pleuræ; but a small area, somewhat variable in size, and usually corresponding with the left half of the lower part of the body of the sternum, and the sternal ends of the cartilages of the fourth and fifth ribs of the left side, comes into direct relationship with the chest-wall. Until puberty or adolescence the lower end of the thymus is in contact with the front of the upper part of the pericardium. *Behind*, the pericardium rests upon the bronchi, the œsophagus, the descending thoracic aorta, and the posterior part of the mediastinal surface of each lung. *Laterally*, it is covered by the pleuræ, and is in relation with the mediastinal surfaces of the lungs; the phrenic nerve, with its accompanying vessels, descends between the pericardium and pleura on either side.

Structure of the pericardium—Although the pericardium is usually described as a single sac, an examination of its structure shows that it consists essentially of two sacs intimately connected with one another, but totally different in structure. The outer sac, known as the *fibrous pericardium*, consists of fibrous tissue. The inner sac, or *serous pericardium*, is a delicate membrane which lies within the fibrous sac and lines its walls; it is composed of a single layer of flattened cells resting on loose connective tissue. The heart invaginates the wall of the serous sac from above and behind, and practically obliterates its cavity, the space being a potential one.

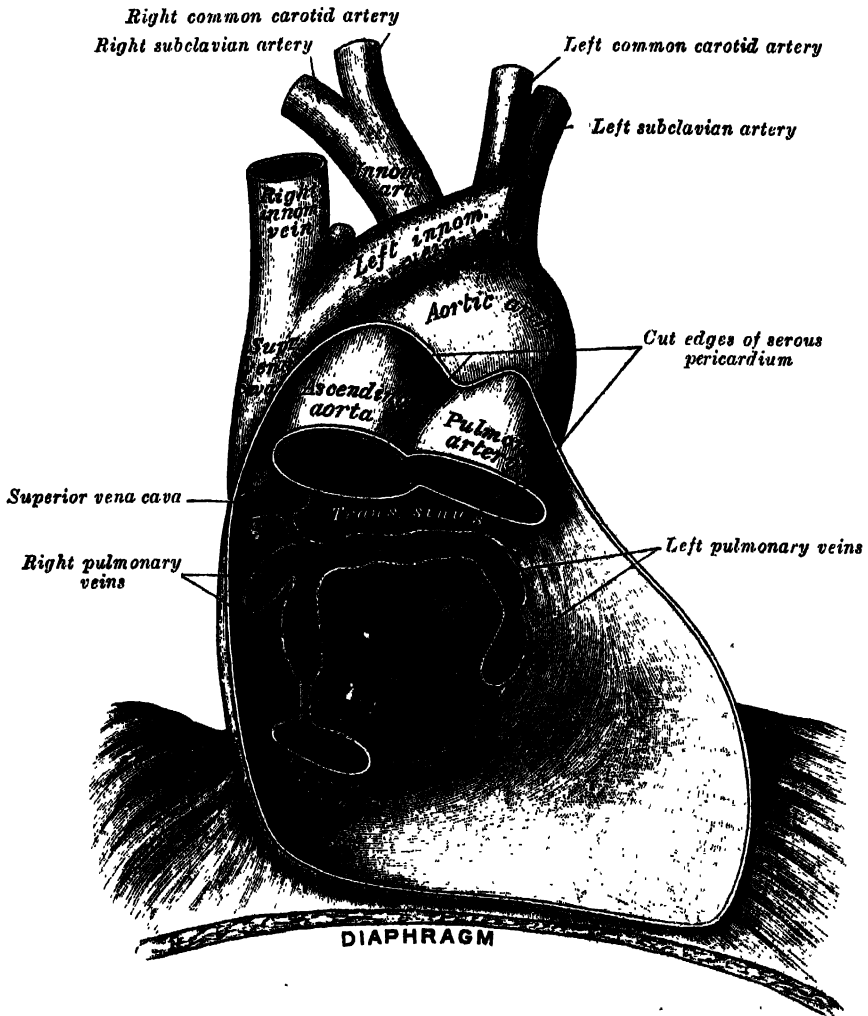
The *fibrous pericardium* forms a flask-shaped bag, the neck of which is closed by its continuity with the external coats of the great vessels, while its base is attached to the central tendon and to the muscular fibres of the left half of the Diaphragm. (In some of the lower mammals the base is either completely separated from the Diaphragm or joined to it by some loose areolar tissue; in man much of its diaphragmatic attachment consists of loose fibrous tissue which can be readily broken down, but over a small area the central tendon of the Diaphragm and the pericardium are fused.) Above, the fibrous pericardium not only blends with the external coats of the great vessels, but is continuous with the pretracheal layer of the deep cervical fascia. By means of these upper and lower connexions it is securely anchored within the thoracic cavity. It is also attached to the posterior surface of the sternum by the *superior* and *inferior sternopericardial ligaments*; the superior passing to the manubrium, and the inferior to the xiphoid process.

The vessels receiving prolongations from the fibrous pericardium are: the aorta, the superior vena cava, the right and left pulmonary arteries, and the four pulmonary veins. The inferior vena cava enters the pericardium through the central tendon of the Diaphragm, and receives no covering from the fibrous layer.

The *serous pericardium* is, as already stated, a closed sac which lines the fibrous pericardium and is invaginated by the heart; it therefore consists of a *visceral* and a *parietal* portion. The visceral portion, or *epicardium*, covers the heart and the great vessels, and from the latter is continuous with the parietal layer which lines the fibrous pericardium. The portion which covers the vessels is arranged in the form of two tubes. The aorta and pulmonary artery are enclosed in one tube, the *arterial mesocardium*. The superior and inferior vena cava and the four pulmonary veins are enclosed in a second

tube, the *venous mesocardium*, the attachment of which to the parietal layer presents the shape of an inverted U. The cul-de-sac enclosed between the limbs of the \cap lies behind the left atrium and is known as the *oblique sinus*, while the passage between the venous and arterial mesocardia—i.e. between the aorta and pulmonary artery in front and the atria behind—is termed the *transverse sinus*.

FIG. 598.—Posterior wall of the pericardial sac, showing the lines of reflection of the serous pericardium on the great vessels.



The ligament of the left vena cava.—Between the left pulmonary artery and subjacent pulmonary vein is a triangular fold of the serous pericardium, known as the *ligament of the left vena cava* (vestigial fold of Marshall). It is formed by the duplicature of the serous layer over the remnant of the lower part of the left superior vena cava (duct of Cuvier). This vein becomes obliterated during foetal life, and remains as a fibrous band stretching from the left superior intercostal vein to the left atrium, where it is continuous with a small vein, the *vein of the left atrium* (oblique vein of Marshall), which opens into the coronary sinus.

The arteries of the pericardium are derived from the internal mammary arteries and their musculophrenic branches, and from the descending thoracic aorta; its nerves are derived from the vagus and phrenic nerves, and the sympathetic trunks.

Applied Anatomy.—Effusion of fluid into the pericardial sac often occurs in acute rheumatism or pneumonia, or in patients with chronic vascular and renal disease, embarrassing the heart's action and giving rise to signs of cardiac distress, such as pallor, a rapid and feeble pulse, dyspnoea, and restlessness. On examination, the apical cardiac impulse is absent, or replaced by a more extensive indefinite and wavering pulsation; it may appear to be in the second, third, or fourth left space, and is then not an apex-impulse, as Potain has stated, but due to the impact of some portion of the heart-wall nearer its base. In children the precordial intercostal spaces may bulge outwards. The most striking sign, however, is the great increase in all directions of the precordial dulness on percussion. This becomes pear-shaped, the stalk of the pear reaching up to about the left sternoclavicular articulation; the dulness also extends some distance to the right of the sternum, particularly in the fifth interspace (Rotch). The fluid collects mainly on either side of the heart, and below it, especially on the left side, where the Diaphragm can yield more readily to pressure than it can on the right. Ewart has drawn attention to the presence of a square patch of dulness over the base of the left lung behind, reaching up to the level of the ninth or tenth rib, and extending laterally as far as the inferior angle of the scapula; the underlying lung-tissue gives the physical signs of compression or collapse.

Paracentesis of the pericardium and withdrawal of the fluid or pus within it, in cases of rheumatic fever or pneumonia, is sometimes necessary to relieve embarrassment of the heart's action. The puncture may be made in the fifth or sixth left intercostal space near the sternum, with care to avoid wounding the internal mammary artery that usually runs 1.25 cm. lateral to the sternal edge. Alternatively the exploring needle may be entered at the left costophrenoid angle, and passed upwards and backwards into the pericardial sac. Curschmann* recommends paracentesis in or lateral to the left mamillary line in the fifth or sixth left interspace, in view of the fact that the fluid tends to collect on either side of and below the heart rather than in front of it.

Pericardiotomy is required when the effusion is of a purulent nature. In this operation a portion of the fifth or sixth costal cartilage is excised. An incision is made along the left border of the sternum from the upper border of the fourth cartilage to the seventh. The fifth costal cartilage is now separated from the sternum and raised, the tissues beneath it being peeled off, so as to avoid wounding the internal mammary artery or the pleura. The fibres of the Transversus thoracis are then separated close to the sternum, and the pericardium felt for and opened, the finger guarding the pleura and left internal mammary artery.

THE HEART (CON)

The heart is a hollow muscular organ of a somewhat conical form; it lies between the lungs in the middle mediastinum and is enclosed in the pericardium (fig. 599). It is placed obliquely in the chest behind the body of the sternum and adjoining parts of the rib cartilages, and projects farther into the left than into the right half of the thoracic cavity, so that about one-third of it is situated on the right and two-thirds on the left of the median plane.

Size.—The heart of the adult measures about 12 cm. from base to apex, 8 to 9 cm. transversely at the broadest part, and 6 cm. anteroposteriorly. Its weight, in the male, varies from 280 to 340 grammes; in the female, from 230 to 280 grammes. It continues to increase in weight and size up to an advanced period of life: this increase is more marked in men than in women.

Component parts.—As already stated (p. 545), the heart is divided into four chambers, viz. right and left atria, and right and left ventricles, the division being indicated on the surface of the heart by grooves or sulci. The atria are separated from the ventricles by the *coronary sulcus* (auriculoventricular groove); this contains the trunks of the coronary vessels of the heart, and is deficient in front, where it is crossed by the root of the pulmonary artery. The *interatrial groove*, separating the two atria, is scarcely marked on the posterior surface, while anteriorly it is hidden by the pulmonary artery and aorta. The ventricles are separated by two grooves, one of which, the *anterior longitudinal sulcus*, is situated on the sternocostal surface of the heart, near its left margin, the other, the *posterior longitudinal sulcus*, on the diaphragmatic surface near the right margin; these grooves extend from the base of the ventricular portion to a notch, the *incisura apicis cordis*, on the acute margin of the heart just to the right of the apex.

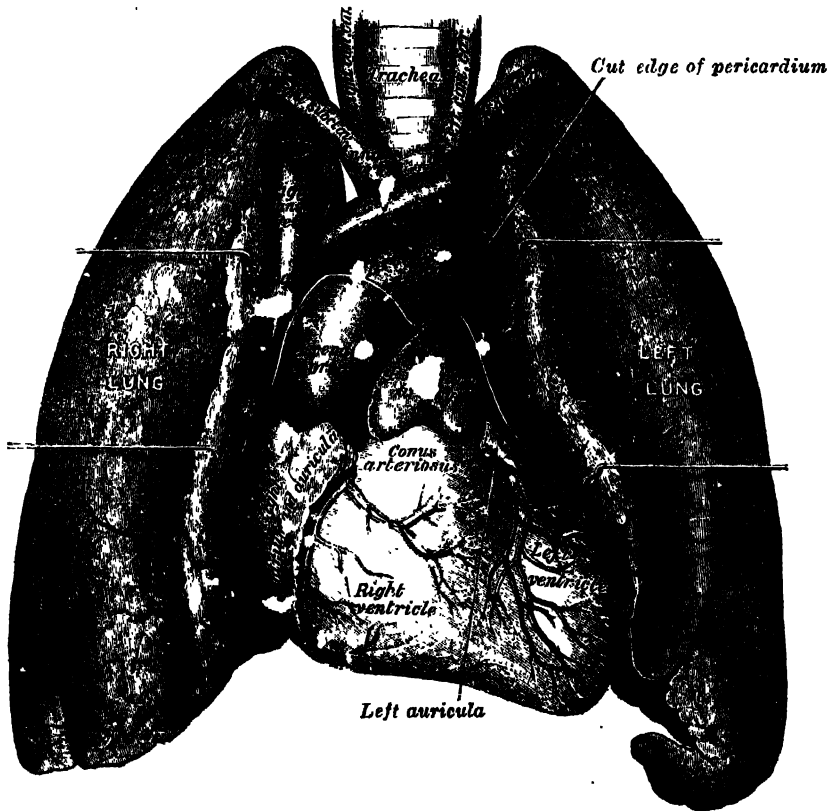
The base (fig. 600) looks upwards, backwards, and to the right, and is separated from the fifth, sixth, seventh, and eighth thoracic vertebrae by the pericardium, oesophagus, aorta, and thoracic duct. It is formed mainly by

* *Therapie der Gegenwart*, 1905.

the left atrium, and, to a small extent, by the back part of the right atrium. Somewhat quadrilateral in form, it is in relation above with the bifurcation of the pulmonary artery, and is bounded below by the posterior part of the coronary sulcus, containing the coronary sinus. On the right it is limited by the sulcus terminalis of the right atrium, and on the left by the ligament of the left vena cava and the oblique vein of the left atrium. The four pulmonary veins, two on either side, open into the left atrium, whilst the superior vena cava opens into the upper part, and the inferior vena cava into the lower part, of the right atrium.

The *apex* is directed downwards, forwards, and to the left, and is overlapped by the left lung and pleura: it lies behind the fifth left intercostal space,

FIG. 599.—Front view of the heart and lungs.



8 to 9 cm. from the mid-sternal line, or, in the male, about 4 cm. below and 2 cm. to the medial side of the left mammary papilla.

The *sternocostal surface* (fig. 601) is directed forwards, upwards, and to the left. Its lower part, formed chiefly by the right ventricle, is convex, and is traversed near its left margin by the anterior longitudinal sulcus. Its upper part, formed by the atria, is separated from the lower by the coronary sulcus; it presents a deep concavity (fig. 603) which is occupied by the ascending aorta and the pulmonary artery.

The *diaphragmatic surface* (fig. 600), directed downwards and slightly backwards, is formed by the ventricles (chiefly by the left ventricle), and rests upon the central tendon and a small part of the left muscular portion of the Diaphragm. It is separated from the base by the posterior part of the coronary sulcus, and is traversed obliquely by the posterior longitudinal sulcus.

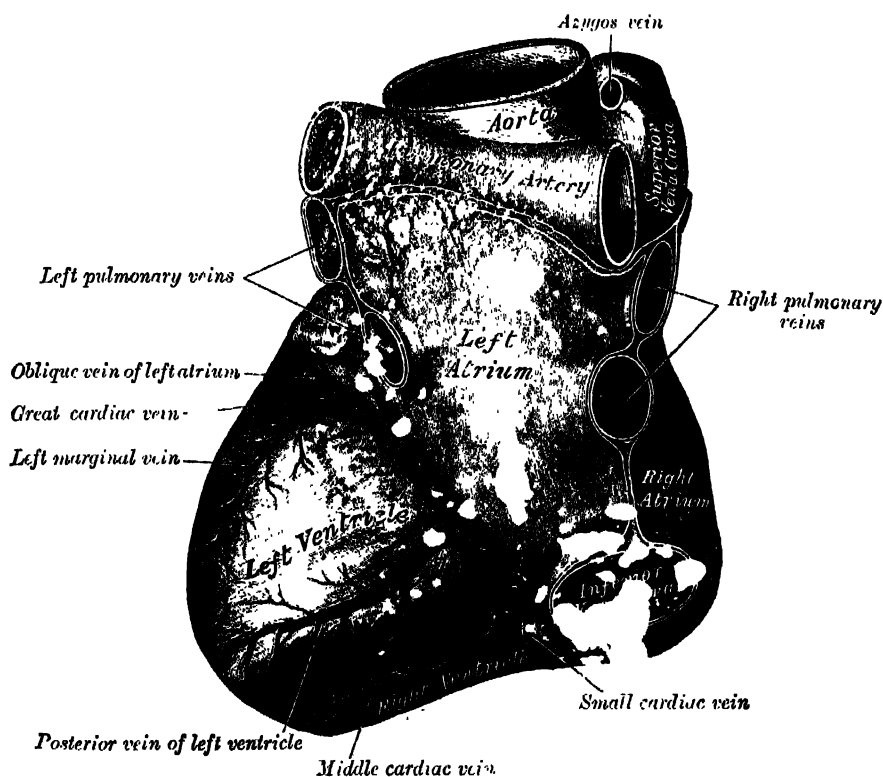
The *right margin* of the heart, formed by the right atrium, is rounded and almost vertical; it is situated behind the third, fourth, and fifth right costal cartilages about 1.25 cm. from the margin of the sternum.

The *inferior or acute margin*, formed by the right ventricle, is nearly horizontal, and extends from the sternal end of the sixth right costal cartilage to the apex of the heart.

The *left or obtuse margin* is full and rounded; it is formed mainly by the left ventricle, but to a slight extent, above, by the left atrium. It extends from a point in the second left intercostal space, about 2.5 cm. from the sternal margin, obliquely downwards, with a convexity to the left, to the apex of the heart.

The *right atrium* is larger than the left, but its walls are somewhat thinner, measuring about 2 mm.; its cavity is capable of containing about 57 c.c. of blood. It consists of two parts: a principal cavity, or *sinus venarum*, situated posteriorly, and an anterior, smaller portion, the *auricula*.

FIG. 600.—The base and diaphragmatic surface of the heart.



The *sinus venarum* is the large quadrangular cavity placed between the two venæ cavæ. Its walls, which are extremely thin, are connected below with the right ventricle, and medially with the left atrium, but are free in the rest of their extent.

The *auricula* is a small, conical, muscular pouch, the margins of which present a dentated edge. It projects from the upper and front part of the sinus forwards and towards the left side, overlapping the root of the aorta.

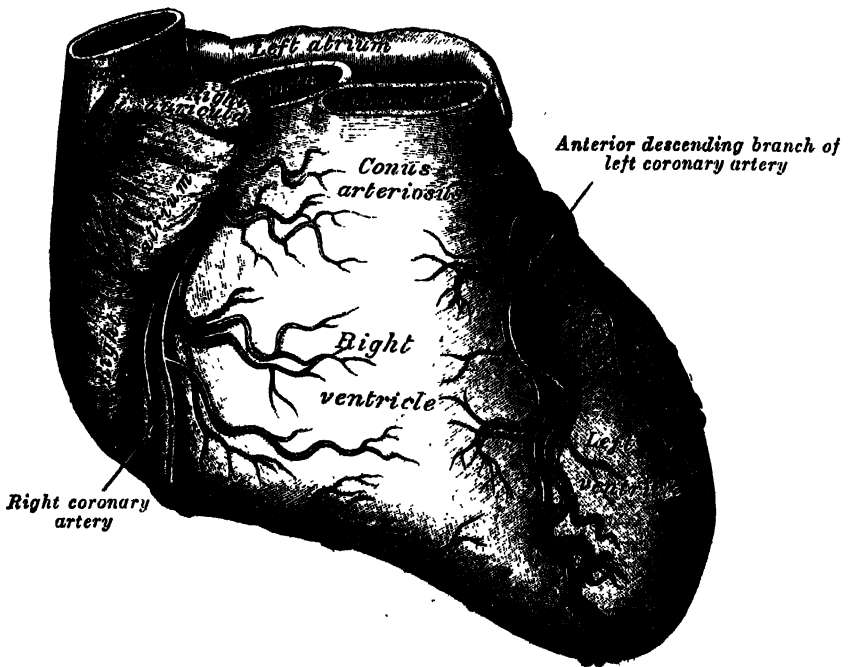
The separation of the auricula from the sinus venarum is indicated externally by a groove, the *sulcus terminalis*, which extends from the front of the superior vena cava to the front of the inferior vena cava, and represents the line of union of the sinus venosus of the embryo with the primitive atrium. On the inner wall of the atrium the separation is marked by a vertical, smooth, muscular ridge, the *crista terminalis*. Behind the crest the internal surface of the atrium is smooth, while in front of it the muscular fibres of the wall are raised into parallel ridges resembling the teeth of a comb, and hence named the *musculi pectinati*.

The interior of the right atrium (fig. 602) presents the following parts for examination :

Orifices	Superior vena cava.	Valves	Valve of the inferior vena cava.
	Inferior vena cava.		Valve of the coronary sinus.
	Coronary sinus.		
	Foramina venarum minimarum.		
	Right atrioventricular.		
	Fossa ovalis.		
	Limbus fossæ ovalis.		
	Intervenous tubercle.		
	Musculi pectinati.		
	Crista terminalis.		

The *superior vena cava* returns the blood from the upper half of the body, and opens into the upper and posterior part of the atrium, the direction of its orifice being downwards and forwards. Its orifice has no valve.

FIG. 601.—Sternocostal surface of heart.



The *inferior vena cava*, larger than the superior, returns the blood from the lower half of the body, and opens into the lowest part of the atrium near the atrial septum; its orifice, directed upwards and backwards, is guarded by a rudimentary valve, the *valve of the inferior vena cava* (valve of Eustachius). The blood entering the atrium through the superior vena cava is directed downwards and forwards towards the atrioventricular orifice, whilst that entering through the inferior vena cava is directed upwards and backwards towards the atrial septum. This is the normal direction of the two currents in fetal life.

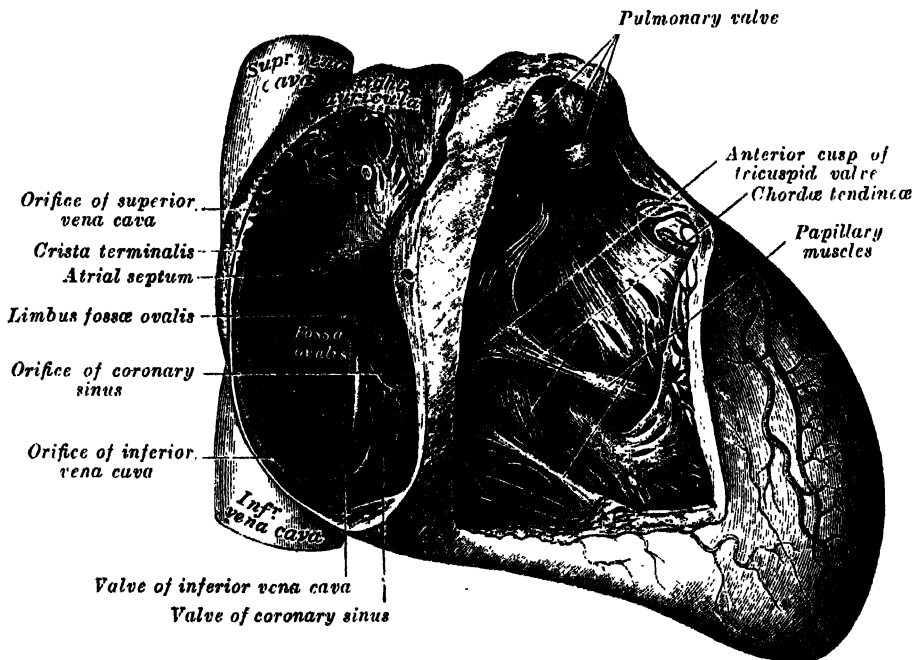
The *coronary sinus* opens into the atrium, between the orifice of the inferior vena cava and the atrioventricular opening. It returns blood from the substance of the heart, and is protected by a semicircular valve, the *valve of the coronary sinus* (valve of Thebesius).

The *foramina venarum minimarum* are the orifices of minute veins (*venæ cordis minimæ*), which return blood directly from the muscular substance of the heart.

The *right atrioventricular orifice* is the large aperture of communication between the atrium and the ventricle; it will be described with the right ventricle.

The *valve of the inferior vena cava* is situated in front of the orifice of the inferior vena cava. It is semilunar in form, its convex margin being attached to the anterior margin of the orifice; its concave margin, which is free, ends in two cornua, of which the left is continuous with the anterior edge of the *limbus fossæ ovalis* while the right is lost on the wall of the atrium. The valve is formed by a duplicature of the lining membrane of the atrium, containing a few muscular fibres. In the *fœtus* this valve is of large size, and serves to direct the blood from the inferior vena cava, through the *foramen ovale*, into the left atrium. In the *adult* it occasionally persists, and may assist in preventing the reflux of blood into the inferior vena cava; more commonly it is small, and may present a cribriform or filamentous appearance; sometimes it is altogether wanting.

FIG. 602.—Interior of right side of heart.



The *valve of the coronary sinus* is a semicircular fold of the lining membrane of the atrium, at the orifice of the coronary sinus. It prevents the regurgitation of blood into the sinus during the contraction of the atrium. This valve may be double or it may be cribriform.

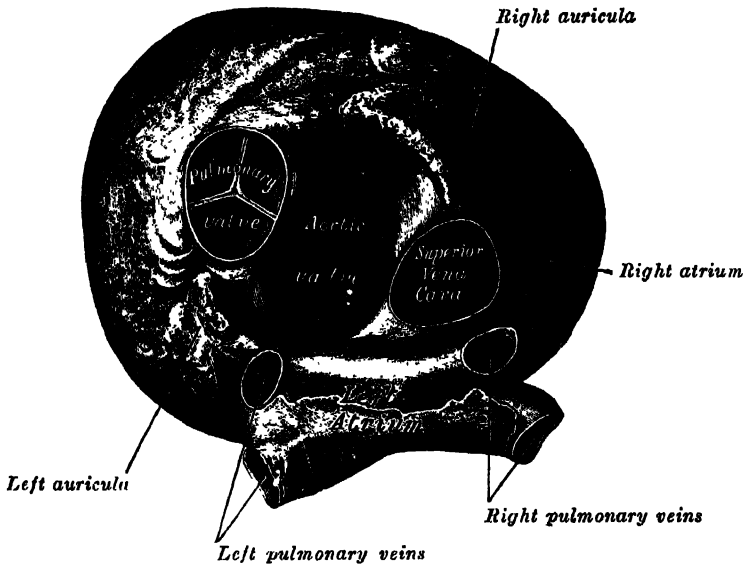
The *fossa ovalis* is an oval depression on the septal wall of the atrium, and corresponds to the situation of the *foramen ovale* in the *fœtus*. It is situated at the lower part of the septum, above and to the left of the orifice of the inferior vena cava.

The *limbus fossæ ovalis* (*annulus ovalis*) is the prominent margin of the *fossa ovalis*. It is most distinct above and at the sides of the fossa; below, it is deficient. A small slit-like valvular opening is occasionally found, at the upper margin of the fossa, leading upwards, beneath the limbus, into the left atrium; it is the remains of the foetal aperture between the two atria.

The *intervenous tubercle* (*tubercle of Lower*) is a small projection on the posterior wall of the atrium, above the *fossa ovalis*. It is distinct in the hearts of quadrupeds, but in man is scarcely visible. During foetal life it may direct the blood from the superior vena cava towards the atrioventricular opening.

The **right ventricle** is triangular in form, and extends from the right atrium to near the apex of the heart. Its anterosuperior surface is rounded and convex, and forms the larger part of the sternocostal surface of the heart. Its under surface is flattened, rests upon the Diaphragm, and forms a small part of the diaphragmatic surface of the heart. Its posterior wall is formed by the ventricular septum, which bulges into the right ventricle, so that a transverse section of the cavity presents a semilunar outline. Its upper left angle forms a conical pouch, the *conus arteriosus*, from which the pulmonary artery arises. A tendinous band, which may be named the *tendon of the conus arteriosus*, extends upwards from the right atrioventricular fibrous ring (p. 562) and connects the posterior surface of the conus arteriosus to the aorta. The wall of the right ventricle is thinner than that of the left, the proportion between them being as 1 to 3; it is thickest at the base, and gradually becomes thinner towards the apex. The cavity equals in size that of the left ventricle, and is capable of holding about 85 c.c. of blood.

FIG. 603.—The heart, seen from above.



Its interior (fig. 602) presents the following parts for examination :

Orifices { Right atrioventricular.
Pulmonary artery.
Trabeculae carneae.

Valves { Tricuspid.
Pulmonary.
Chordae tendineae.

The **right atrioventricular orifice** is the large oval aperture of communication between the right atrium and ventricle. Situated at the base of the ventricle, it measures about 4 cm. in diameter and is encircled by a fibrous ring, covered by the lining membrane of the heart; it is considerably larger than the left atrioventricular orifice, being sufficient to admit the ends of four fingers. It is guarded by the tricuspid valve.

The **orifice of the pulmonary artery** is circular in form, and situated at the summit of the conus arteriosus, close to the ventricular septum. It is placed above and to the left of the atrioventricular opening, and is guarded by the pulmonary semilunar valves.

The **tricuspid valve** (figs. 602, 604) consists of three somewhat triangular cusps or segments. The largest cusp is interposed between the atrioventricular orifice and the conus arteriosus, and is termed the anterior cusp. A second, the posterior cusp, is in relation to the right margin of the ventricle, and a third, the medial cusp, to the ventricular septum. They are formed by duplicatures of the lining membrane of the heart, strengthened by intervening

layers of fibrous tissue: their central parts are comparatively thick and strong, their marginal portions thin and translucent, and in the angles between the latter small intermediate segments are sometimes seen. Their bases are attached to a fibrous ring surrounding the atrioventricular orifice and are also joined to each other so as to form a continuous annular membrane, while their apices project into the ventricular cavity. Their atrial surfaces, directed towards the blood-current from the atrium, are smooth; their ventricular surfaces, directed towards the wall of the ventricle, are rough and irregular and, together with the apices and margins of the cusps, give attachment to a number of delicate tendinous cords, the *chordæ tendineæ*.

The *trabeculæ carneæ* are rounded or irregular muscular columns which project from the whole of the inner surface of the ventricle, with the exception of the conus arteriosus. They are of three kinds: some are ridges, others are fixed at their extremities but free in the middle, while a third set (*musculi papillares*) are continuous by their bases with the wall of the ventricle, while their apices project into the cavity, and give origin to the *chordæ tendineæ* which pass to be attached to the segments of the tricuspid valve. There are two papillary muscles, anterior and posterior: of these, the anterior is the larger, and its *chordæ tendineæ* are connected with the anterior and posterior cusps of the valve; the posterior sometimes consists of two or three parts, and its *chordæ tendineæ* are connected with the posterior and medial cusps. Some *chordæ tendineæ* also spring directly from the ventricular septum, or from small papillary eminences on it, and pass to the anterior and medial cusps. A muscular band, well marked in sheep and some other animals, frequently extends from the base of the anterior papillary muscle to the ventricular septum. From its attachments it may assist in preventing over-distension of the ventricle, and so has been named the *moderator band*.

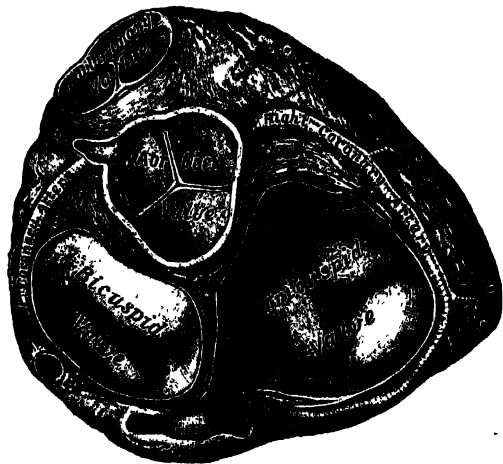
The *pulmonary semilunar valves* (figs. 602, 603) are three in number, two in front and one behind, formed by duplicatures of the lining membrane, strengthened by fibrous tissue. They are attached, by their convex margins, to the wall of the pulmonary artery at its junction with the ventricle, their free borders being directed upwards into the lumen of the vessel. The free and attached margins of each are strengthened by tendinous fibres, and the former presents, at its middle, a thickened nodule (*corpus Arantii*). From this nodule tendinous fibres radiate through the segment to its attached margin, but are absent from two narrow crescentic portions, the *lunula*, placed one on either side of the nodule immediately adjoining the free margin (fig. 606). Between the semilunar valves and the wall of the pulmonary artery are three pouches or sinuses (*sinuses of Valsalva*).

The *left atrium* is rather smaller than the right, but its walls are thicker, measuring about 3 mm.; it consists, like the right, of two parts, a *principal cavity* and an *auricula*.

The *principal cavity* is cuboidal in form, and concealed, in front, by the pulmonary artery and aorta; in front and to the right, it is separated from the right atrium by the atrial septum; opening into it on either side are the two pulmonary veins.

The *auricula* is somewhat constricted at its junction with the principal cavity; it is longer, narrower, and more curved than that of the right atrium,

FIG. 604.—The bases of the ventricles, exposed by removal of the atria.



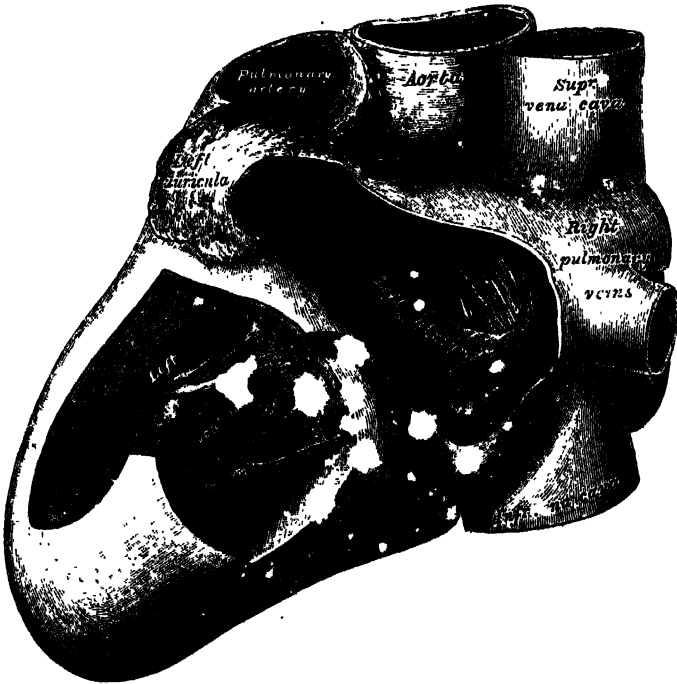
and its margins are more deeply indented. It is directed forwards and towards the right, and overlaps the root of the pulmonary artery.

The interior of the left atrium (fig. 605) presents the following parts for examination :

Orifices of the four pulmonary veins.
Left atrioventricular orifice.
Foramina venarum minimarum.
Musculi pectinati.

The *pulmonary veins*, four in number, open into the upper part of the posterior surface of the left atrium—two on either side of its middle line : they are not provided with valves. The two left veins frequently end by a common opening.

FIG. 605.—Interior of left side of heart.



The *left atrioventricular orifice* is the aperture between the left atrium and ventricle ; it is smaller than the right atrioventricular orifice.

The *foramina venarum minimarum* are the orifices of minute veins (*venæ cordis minimæ*) which return blood directly from the muscular substance of the heart.

The *musculi pectinati*, fewer and smaller than those in the right atrium, are confined to the inner surface of the auricle.

On the atrial septum may be seen a lunate impression, bounded below by a crescentic ridge, the concavity of which is turned upwards. The depression is just above the fossa ovalis of the right atrium.

The *left ventricle* is longer and more conical in shape than the right, and on transverse section its cavity presents an oval or nearly circular outline. It forms a small part of the sternocostal, and a considerable part of the diaphragmatic, surface of the heart ; it also forms the apex of the heart. Its walls are about three times as thick as those of the right ventricle.

Its interior (fig. 605) presents the following parts for examination :

Orifices { Left atrioventricular.
Aortic.
Trabeculæ carneæ.

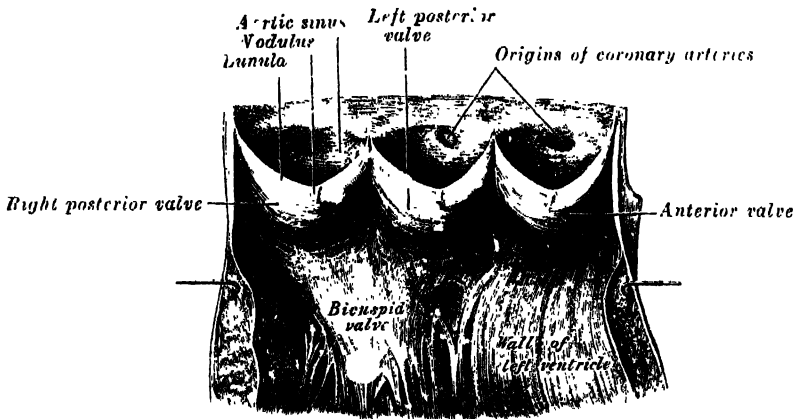
Valves { Bicuspid or mitral.
Aortic.
Chordæ tendineæ.

The *left atrioventricular orifice* is placed below and to the left of the *aortic orifice*. It is a little smaller than the right atrioventricular orifice, admitting only three fingers. It is surrounded by a dense fibrous ring and is guarded by the bicuspid or mitral valve.

The *aortic orifice* is a circular aperture in front and to the right of the atrioventricular orifice, from which it is separated by the anterior cusp of the bicuspid valve. Its orifice is guarded by the *aortic semilunar valves*. The portion of the ventricle immediately below the aortic orifice is termed the *aortic vestibule*, and possesses fibrous instead of muscular walls.

The *bicuspid* or *mitral valve* (figs. 604, 605) is attached to the circumference of the left atrioventricular orifice in the same way that the tricuspid valve is on the right side. It consists of two triangular cusps, formed by duplicatures of the lining membrane, strengthened by fibrous tissue, and containing a few muscular fibres. The cusps are of unequal size, and are larger, thicker, and stronger than those of the tricuspid valve. The larger cusp is placed in front and to the right between the atrioventricular and aortic orifices, and is known as the *anterior* or *aortic cusp*; the smaller or *posterior cusp* is placed behind and

FIG. 606.-Aorta laid open to show the semilunar valves.



to the left of the opening. Two smaller cusps are usually found at the angles of junction of the larger. The cusps of the bicuspid valve are furnished with chordæ tendineæ, which are attached in a manner similar to those on the right side of the heart; they are, however, thicker, stronger, and less numerous.

The *aortic semilunar valves* (figs. 604, 606) are three in number, and surround the orifice of the aorta; two are posterior (right and left) and one is anterior. They are similar in structure, and in their mode of attachment, to the pulmonary semilunar valves, but are larger, thicker, and stronger; the lunulæ are more distinct, and the noduli or corpora Arantii thicker and more prominent. Opposite the valves the aorta presents slight dilatations, the *aortic sinuses* (sinuses of Valsalva) which are larger than those at the origin of the pulmonary artery.

The *trabeculæ carneæ* are of three kinds, like those in the right ventricle, but they are more numerous, and present a dense interlacement, especially at the apex, and upon the posterior wall, of the ventricle. The *musculi papillares* are two in number, one springing from the anterior, the other from the posterior wall; they are of large size, and end in rounded extremities from which the chordæ tendineæ arise. The chordæ tendineæ from each papillary muscle are connected to both cusps of the bicuspid valve.

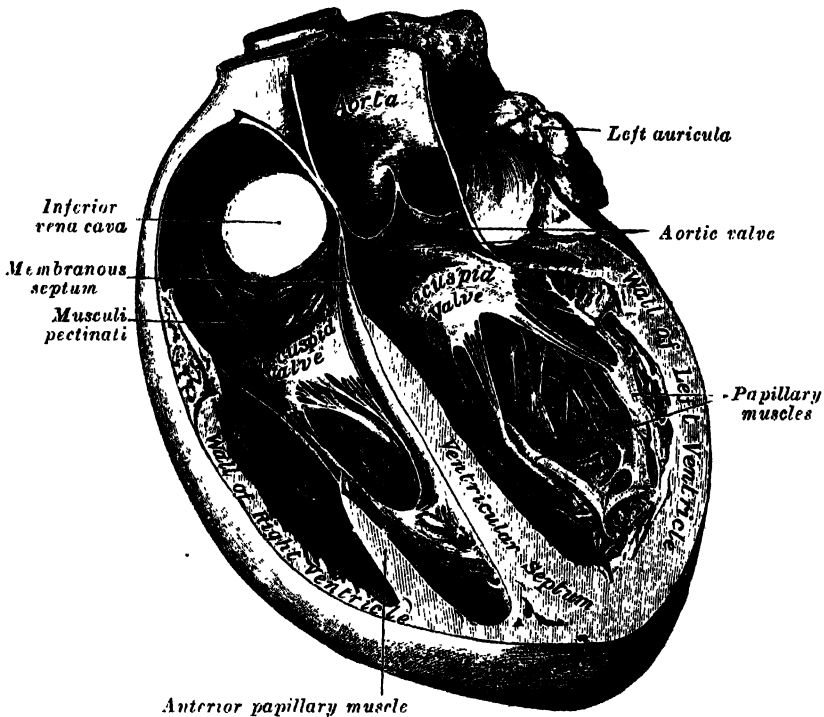
The *ventricular septum* (fig. 607) is directed obliquely backwards and to the right, and is curved with the convexity towards the right ventricle; its margins correspond with the anterior and posterior longitudinal sulci on the surface of the heart. The greater portion of the septum is thick and muscular.

and constitutes the *muscular ventricular septum*; but its upper and posterior part, which separates the aortic vestibule from the lower part of the right atrium and upper part of the right ventricle, is thin and fibrous, and is termed the *membranous ventricular septum*. An abnormal communication may exist between the ventricles at this part, owing to defective development of the membranous septum.

Structure.—The heart consists of muscular fibres (*myocardium*), and of fibrous rings which serve for their attachment. It is covered by the visceral layer of the serous pericardium (*epicardium*), and lined by the *endocardium*.

The *endocardium* is a thin, smooth, glistening membrane which lines the inner surface of the heart; it assists in forming the valves by its reduplications, and is

FIG. 607.—Section of the heart showing the ventricular septum.



continuous with the lining membrane of the large blood-vessels. It consists of a layer of endothelial cells placed on a stratum of connective tissue and elastic fibres.

The *fibrous rings* surround the atrioventricular and arterial orifices, and are stronger on the left than on the right side of the heart. The atrioventricular rings serve for the attachment of the muscular fibres of the atria and ventricles, and for the attachment of the bicuspid and tricuspid valves. The left atrioventricular ring is closely connected, by its right margin, with the aortic arterial ring; between these and the right atrioventricular ring is a triangular mass of fibrous tissue, the *trigonum fibrosum*, which represents the *os cordis* of some of the larger animals, as the ox and elephant. There is also the tendon of the conus arteriosus, already referred to (p. 558).

The fibrous rings surrounding the arterial orifices serve for the attachment of the great vessels and semilunar valves. Each ring receives, by its ventricular margin, the attachment of some of the muscular fibres of the ventricles; its opposite margin presents three deep semicircular notches, to which the middle coat of the artery is firmly fixed. The attachment of an artery to its fibrous ring is strengthened by the external coat and epicardium externally, and by the endocardium internally. From the margins of the semicircular notches, the fibrous structure of the ring

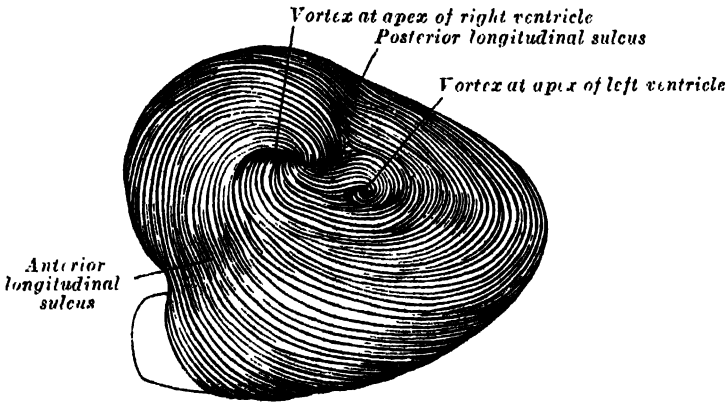
is continued into the segments of the valves. The middle coat of the artery in this situation is thin, and the vessel is dilated to form the sinuses of the aorta and pulmonary artery.

The *muscular structure of the heart* consists of fibres, which are transversely and longitudinally striated (page 33), and present an exceedingly intricate interlacement. They comprise (a) the fibres of the atria, (b) the fibres of the ventricles, and (c) the atrioventricular bundle.

The *fibres of the atria* are arranged in two layers—a superficial, common to both atria, and a deep, proper to each. The *superficial fibres* are most distinct on the front of the atria, across the bases of which they run in a transverse direction, forming a thin and incomplete layer; some of them pass into the atrial septum. The *deep fibres* consist of looped and annular fibres. The *looped fibres* pass upwards over each atrium, and are attached by their extremities to the corresponding atrioventricular ring, in front and behind; the *annular fibres* surround the auriculæ, and form annular bands around the terminations of the veins and around the fossa ovalis.

The *fibres of the ventricles* are arranged in a complex manner, and various accounts have been given of their course and connexions; the following description is based

FIG. 608.—Apex of the heart to show the two vortices. (Mall.)

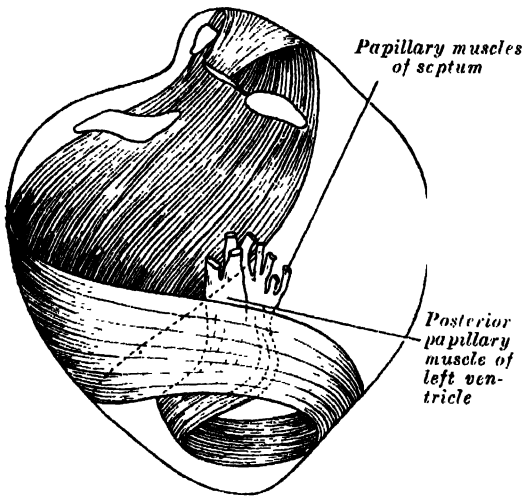


on that given by John Bruce MacCallum.* They consist of superficial and deep layers, all of which, with the exception of two, are inserted into the papillary muscles of the ventricles. The *superficial layers* comprise the following: (a) Fibres which spring from the tendon of the conus arteriosus (p. 558) and sweep downwards and towards the left across the anterior longitudinal sulcus and around the apex of the heart, where they form a vortex (fig. 608) and pass upwards and inwards to terminate in the papillary muscles of the left ventricle; those arising from the upper half of the tendon of the conus arteriosus pass to the anterior papillary muscle, those from the lower half to the posterior papillary muscle and the papillary muscles of the septum (fig. 609). (b) Fibres which arise from the right atrioventricular ring and run diagonally across the diaphragmatic surface of the right ventricle and round its right border on to its sternocostal surface, where they dip beneath the fibres just described, and, crossing the anterior longitudinal sulcus, wind around the apex of the heart and end in the posterior papillary muscle of the left ventricle. (c) Fibres which spring from the left atrioventricular ring, and, crossing the posterior longitudinal sulcus, pass successively into the right ventricle and end in its papillary muscles. The *deep layers* are three in number; they arise in the papillary muscles of one ventricle and, curving in an S shaped manner, turn in at the longitudinal sulcus and end in the papillary muscles of the other ventricle (fig. 610). The layer which is most superficial in the right ventricle lies next the lumen of the left, and vice versa. Those of the first layer almost encircle the right ventricle, and, crossing in the septum to the left, unite with

* *Johns Hopkins Hospital Reports*, vol. ix.

the superficial fibres from the right atrioventricular ring to form the posterior papillary muscle. Those of the second layer have a less extensive course in the wall of the right ventricle, and a correspondingly greater course in the left, where they join with the superficial fibres from the anterior half of the tendon of the conus arteriosus

FIG. 609.—Diagram of the superficial muscular fibres of the ventricles of the heart originating in the tendon of the conus arteriosus. (After MacCallum.)

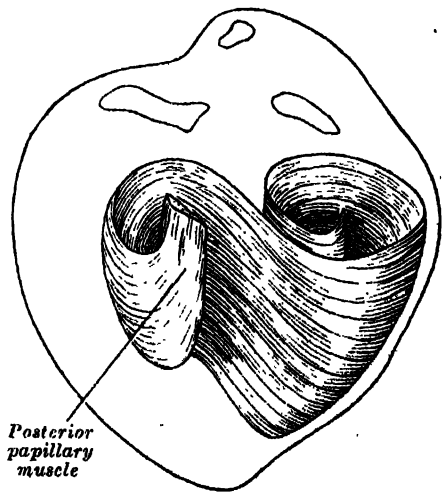


to form the papillary muscles of the septum. Those of the third layer pass almost entirely round the left ventricle and unite with the superficial fibres from the lower half of the tendon of the conus arteriosus to form the anterior papillary muscle. Besides the layers just described there are two bands which do not end in papillary muscles. One springs from the right atrioventricular ring, crosses in the atrioventricular septum, encircles the deep layers of the left ventricle, and ends in the left atrioventricular ring. The second band is apparently confined to the left ventricle; it is attached to the left atrioventricular ring, and encircles the portion of the ventricle adjacent to the aortic orifice.

The *atrioventricular bundle* is a direct muscular connexion between the atria and the

ventricles. It arises in connexion with two small collections of spindle-shaped cells, the sino-atrial and atrioventricular nodes. The *sino-atrial node* is situated on the anterior border of the opening of the superior vena cava; from it strands of fusiform fibres run under the endocardium of the wall of the atrium to the atrioventricular node. The *atrioventricular node* lies near the orifice of the coronary sinus in the annular and septal fibres of the right atrium; from it the atrioventricular bundle passes forwards below the membranous septum, and divides into right and left fasciculi. These run down in the right and left ventricles, one on either side of the ventricular septum, covered by endocardium. In the lower parts of the ventricles they break up into numerous strands which end in an intricate network in the papillary muscles and ventricular muscle generally. The bundle, and its divisions are enveloped in a sheath of connective tissue; by injecting this sheath with Indian ink the ramifications of the bundle can be demonstrated. The greater portion of the atrioventricular bundle consists of narrow, somewhat fusiform fibres, but its terminal strands are composed of Purkinje fibres.

FIG. 610.—Diagram of the course of the deepest layer of the left ventricle. (After MacCallum.)



Kent has described a second atrioventricular bundle in the right lateral aspect of the heart, containing cardiac muscle-fibres, fine nerve-fibres, and fibres resembling those of Purkinje. This bundle is connected with a node in the wall of the right atrium, formed of fine, faintly striated muscle-fibres.

A. Morison * has shown that in the sheep and pig the atrioventricular bundle 'is a great avenue for the transmission of nerves from the auricular to the ventricular heart'; large and numerous nerve-trunks enter the bundle and course with it. Branches arise from these nerve-trunks and form plexuses around groups of Purkinje cells, and from these plexuses fine fibrils go to innervate individual cells.

Applied Anatomy.—Clinical and experimental evidence go to prove that this bundle conveys the impulse to systolic contraction from the atrial septum to the ventricles, and much attention has recently been paid to it, because it appears to become fibrosed and to lose much of its conducting power (heart-block) in many cases of Adams-Stokes' syndrome. This condition is characterised by a slow pulse, a tendency to syncopal or epileptiform seizures, and the fact that while the cardiac atria beat at a normal rate, the ventricles contract much less frequently.

Vessels and Nerves.—The *arteries* supplying the heart are the right and left coronary branches of the aorta; the majority of the *veins* drain into the right atrium, but the left atrium receives a few minute veins from the adjacent part of the heart.

The *lymphatics* end in the thoracic and right lymphatic ducts.

The *nerves* are derived from the cardiac plexus, which is formed by branches from the vagi and sympathetic. They are freely distributed both on the surface and in the substance of the heart, the separate nerve-filaments being furnished with small ganglia. The atrioventricular bundle receives nerve-fibres from ganglia in the atrial septum. Other ganglia are found in relation with the sino-atrial node, and supply it with nerve-filaments.

The cardiac cycle and the actions of the valves.—By the contractions of the heart the blood is pumped through the arteries to all parts of the body. These contractions occur regularly and at the rate of about seventy per minute. Each wave of contraction or *period of activity* is followed by a *period of rest*, the two periods constituting what is known as a *cardiac cycle*.

Each cardiac cycle consists of three phases, which succeed each other as follows: (1) a short simultaneous contraction of both atria, termed the *atrial systole*, followed, after a slight pause, by (2) a simultaneous, but more prolonged, contraction of both ventricles, named the *ventricular systole*, and (3) a *period of rest*, during which the whole heart is relaxed. The atrial contraction commences around the venous openings, and sweeping over the atria forces their contents through the atrio-ventricular openings into the ventricles, regurgitation into the veins being prevented by the contraction of their muscular coats. When the ventricles contract, the tricuspid and bicuspid valves are closed, and prevent the passage of the blood back into the atria; the *musculi papillares* at the same time are shortened, and, pulling on the chordæ tendinæ, prevent the inversion of the valves into the atria. As soon as the pressure in the ventricles exceeds that in the pulmonary artery and aorta, the valves guarding the orifices of these vessels are opened, and the blood is driven from the right ventricle into the pulmonary artery, and from the left into the aorta. The moment the systole of the ventricles ceases, the pressure of the blood in the pulmonary artery and aorta closes the pulmonary and aortic semilunar valves, thus preventing regurgitation of blood into the ventricles, and the valves remain shut until re-opened by the next ventricular systole. During the period of rest the tension of the tricuspid and bicuspid valves is relaxed, and blood flows from the veins through the atria into the ventricles. The filling of the ventricles is completed by the systole of the atria. The average duration of a cardiac cycle is about $\frac{8}{10}$ of a second, made up as follows:

Atrial systole, $\frac{1}{10}$.	Atrial diastole, $\frac{7}{10}$.
Ventricular systole, $\frac{3}{10}$.	Ventricular diastole, $\frac{5}{10}$.
Total systole, $\frac{4}{10}$.	Complete diastole, $\frac{4}{10}$.

The rhythmical action of the heart is *muscular* in origin—that is to say, the heart-muscle itself possesses the inherent property of contraction apart from any nervous stimulation. The more embryonic the muscle the better is it able to initiate the contraction wave; this explains why the normal systole of the heart starts at the entrance of the veins, for there the muscle is most embryonic in nature. A slight pause occurs between systole of the atria and that of the ventricles. This

* *Journal of Anatomy and Physiology*, vol. xlvii.

is due to the fact that the contraction of the ventricles is excited by an impulse conveyed by the atrioventricular bundle, conduction along the fibres of which is relatively slow. The nerves, although not concerned in originating the contractions of the heart-muscle, play an important rôle in regulating their force and frequency in order to subserve the physiological needs of the organism.

Applied Anatomy.—Wounds of the heart are often immediately fatal, but not necessarily so. They may be non-penetrating, when death may occur from hæmorrhage if one of the coronary vessels has been wounded, or subsequently from pericarditis. Even a penetrating wound is not necessarily fatal, as many cases have been recorded in which the wound has been sutured successfully.

CHIEF PECULIARITIES IN THE VASCULAR SYSTEM OF THE FŒTUS

The development of the heart and vascular system is described on pages 109 to 128.

The chief peculiarities of the foetal heart are the direct communication between the atria through the foramen ovale, and the large size of the valve of the inferior vena cava. Amongst other peculiarities the following may be noted: (1) In early foetal life the heart lies immediately below the mandibular arch, and as development proceeds it is gradually drawn within the thorax. (2) For a time the atrial portion exceeds the ventricular in size, and the walls of the ventricles are of equal thickness; towards the end of foetal life the ventricular portion becomes the larger, and the wall of the left ventricle exceeds that of the right in thickness. (3) Its size is large as compared with that of the rest of the body, the proportion at the second month being 1 to 50, and at birth 1 to 120, while in the adult the average is about 1 to 160.

The *foramen ovale* forms a free communication between the atria until the end of foetal life: it is obliterated shortly after birth (pages 115, 116).

The *valve of the inferior vena cava* directs the blood from that vessel through the foramen ovale into the left atrium.

The chief peculiarities in the arterial system of the foetus are the communication between the pulmonary artery and the aorta by means of the ductus arteriosus, and the continuation of the hypogastric arteries as the umbilical arteries to the placenta.

The *ductus arteriosus* is a short tube, about 1.25 cm. in length at birth, and of the diameter of a goose-quill. In early foetal life it forms the continuation of the pulmonary artery, and opens into the aorta, just beyond the origin of the left subclavian artery; and so conducts the greater amount of the blood from the right ventricle into the aorta. When the branches of the pulmonary artery have become larger relatively to the ductus arteriosus, the latter is chiefly connected to the left pulmonary artery. It is obliterated within a few days after birth.

In the foetus the *hypogastric arteries* are continued along the sides of the urinary bladder, thence upwards on the back of the anterior abdominal wall to the umbilicus; here they pass out of the abdomen and run, under the name of the *umbilical arteries*, in the umbilical cord to the placenta. They convey blood from the foetus to the placenta.

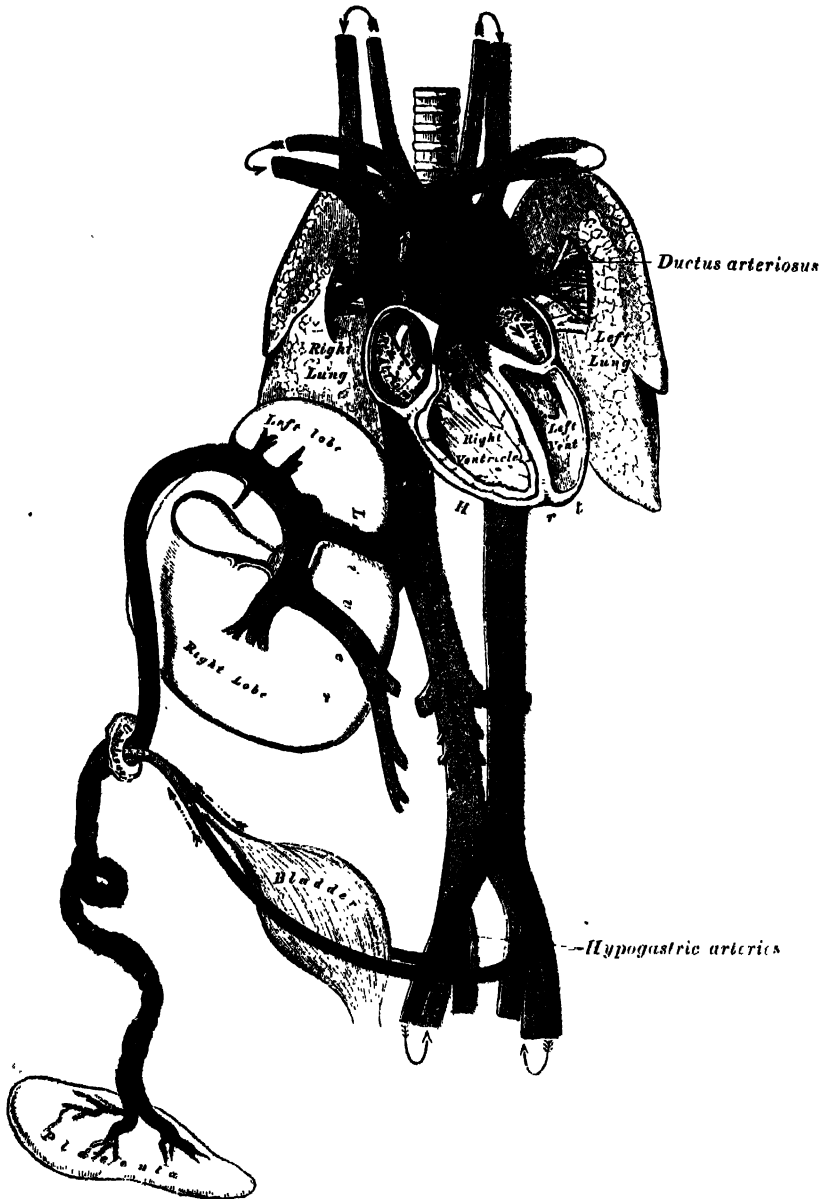
The chief peculiarities in the venous system of the foetus are the communications established between the placenta and the liver and portal vein, through the umbilical vein; and between the umbilical vein and the inferior vena cava through the ductus venosus.

THE FŒTAL CIRCULATION (fig. 611)

The foetal blood is carried to the placenta by the hypogastric and umbilical arteries, and returned from the placenta to the foetus by the two umbilical veins. These veins unite in the umbilical cord to form a single vein (*vena umbilicalis impar*) which divides within the embryo into a right and a left umbilical vein. After the formation of the liver the right umbilical vein atrophies and disappears, but the left persists until the end of foetal life. It enters the abdomen at the umbilicus, and passes along the free margin of the falciform

ligament of the liver, to the under surface of that organ, where it gives off two or three branches, one of large size to the left lobe, and others to the lobus quadratus and lobus caudatus. At the porta hepatis or transverse fissure

FIG. 611.—Plan of the foetal circulation.



In this plan the arrows represent the course which the blood takes in the heart and vessels.

of the liver it divides into two branches : of these, the larger is joined by the portal vein, and enters the right lobe ; the smaller is continued upwards, under the name of the ductus venosus, and joins the inferior vena cava. The blood conveyed by the left umbilical vein passes to the inferior vena cava in three different ways. Some enters the liver directly and is carried to the inferior vena cava by the hepatic veins ; a considerable quantity circulates

through the liver with the portal venous blood, before entering the inferior vena cava by the hepatic veins; the remainder passes directly into the inferior vena cava through the ductus venosus.

In the inferior vena cava, the blood carried by the ductus venosus and hepatic veins mixes with that returning from the lower extremities and abdominal wall. It enters the right atrium, and, guided by the valve of the inferior vena cava, passes through the foramen ovale into the left atrium, where it mingles with a small quantity of blood returned from the lungs by the pulmonary veins. From the left atrium it passes into the left ventricle, and from that cavity into the aorta, by means of which it is distributed almost entirely to the head and upper extremities, a small quantity being probably carried into the descending aorta. The blood from the head and upper extremities is returned by the superior vena cava to the right atrium, where it mixes with a small portion of that returned by the inferior vena cava. From the right atrium the blood passes into the right ventricle, and thence into the pulmonary artery. The lungs of the foetus being inactive, only a small quantity of the blood conveyed by the pulmonary artery is distributed to them by the right and left pulmonary arteries, and returned by the pulmonary veins to the left atrium: the greater part passes through the ductus arteriosus into the aorta, where it mixes with the small quantity of blood transmitted by the left ventricle into this part of the aorta. It descends through the aorta and is in part distributed to the lower extremities and the viscera of the abdomen and pelvis, but most of it is conveyed by the umbilical arteries to the placenta.

From the preceding account of the circulation of the blood in the foetus the following facts will be evident: 1. The placenta serves the purposes of nutrition and excretion, receiving the impure blood from the foetus, and returning it purified and charged with additional nutritive material. 2. A large part of the blood of the left umbilical vein traverses the liver before entering the inferior vena cava; this is correlated with the large size of the liver, especially at an early period of foetal life. 3. The right atrium is the point of meeting of a double current, the blood from the inferior vena cava being guided by the valve of this vessel through the foramen ovale into the left atrium, while that in the superior vena cava descends into the right ventricle. At an early period of foetal life it is highly probable that the two streams are quite distinct, for the inferior vena cava opens almost directly into the left atrium, and the valve of the inferior vena cava would exclude the current from the right ventricle. At a later period, as the separation between the two atria becomes more distinct, it seems probable that some mixture of the two streams must take place. 4. The pure blood carried from the placenta to the foetus, mixed with the blood from the portal vein and inferior vena cava, passes almost directly to the arch of the aorta, and is distributed by the branches of that vessel to the head and upper extremities. 5. The blood contained in the descending aorta, chiefly derived from that which has already circulated through the head and limbs, together with a small quantity from the left ventricle, is distributed to the abdomen and lower extremities.

CHANGES IN THE VASCULAR SYSTEM AT BIRTH

At birth, when respiration is established, an increased amount of blood from the pulmonary artery passes through the lungs, and the placental circulation is cut off. The foramen ovale is closed by the septum secundum (p. 115) about the tenth day after birth; sometimes a slit-like opening is left between the two atria.

The *ductus arteriosus* begins to contract immediately after respiration is established, and is completely closed between the fourth and tenth days; it ultimately forms an impervious cord, the *ligamentum arteriosum*, which connects the left pulmonary artery to the arch of the aorta.

Of the *hypogastric arteries*, the parts extending from the sides of the bladder to the umbilicus become obliterated between the second and fifth days after birth, and project as fibrous cords, termed the lateral umbilical ligaments, towards the abdominal cavity, carrying on them folds of peritoneum.

The *left umbilical vein* and the *ductus venosus* are completely obliterated between the second and fifth days after birth; the former becomes the ligamentum teres, the latter the ligamentum venosum, of the liver.

THE ARTERIES

The distribution of the systemic arteries is like a highly branched tree, the common trunk of which, formed by the aorta, commences at the left ventricle, while the smallest ramifications extend to the peripheral parts of the body and the contained organs. Arteries are found in all parts of the body, except in the hairs, nails, epidermis, cartilages, and cornea; the larger trunks usually occupy the most protected situations, running, in the limbs, along the flexor surfaces, where they are less exposed to injury.

There is considerable variation in the mode of division of the arteries: occasionally a short trunk subdivides into several branches at the same point, as in the coeliac artery and the thyrocervical trunk; usually the vessel gives off several branches in succession, and still continues as the main trunk, as in the arteries of the limbs.

A branch of an artery is smaller than the trunk from which it arises; but if an artery divides into two branches, the combined sectional area of the two vessels is, in nearly every instance, somewhat greater than that of the trunk; and the combined sectional area of all the arterial branches greatly exceeds that of the aorta.

The arteries unite with one another, forming what are called *anastomoses*. Anastomosis between trunks of nearly equal size is found in the brain, where the two vertebral arteries unite to form the basilar, and the two anterior cerebral arteries are connected by the anterior communicating artery; and in the abdomen, where the intestinal arteries have very ample anastomoses between their larger branches. In the limbs, the anastomoses are largest and most numerous around the joints; the branches arising from an artery above the joint uniting with branches from the vessels below. These anastomoses are of considerable interest to the surgeon, as it is by their enlargement that a *collateral circulation* is established after the application of a ligature to a main artery. The smaller branches of arteries anastomose more frequently than the larger; and between the smallest twigs these anastomoses are so numerous that they constitute a close network pervading nearly every tissue of the body.

Applied Anatomy.—The walls of all the arteries, and most of all of the aorta, are liable to various forms of hardening known collectively as *arteriosclerosis*, with loss of elasticity, that are of the greatest clinical importance. The two chief varieties of arteriosclerosis are: (1) hypertrophy of the muscular tunica media of the arteries, clinically associated with chronic arterial vasoconstriction and high blood-pressure, and (2) atheroma or atherosclerosis, essentially a senile degenerative change of the intima, that leads to loss of arterial elasticity by the replacement of elastic by fibrous tissue. Whatever the cause of arterial sclerosis its chief ill-effects on the patient are two. In the first place, it is associated with a permanent and often considerable rise in the arterial blood-pressure, entailing a corresponding hypertrophy of the heart: in the second, it weakens the vessel walls, rendering them more liable to rupture, while at the same time it is apt to lessen the calibre of the affected vessels.

The arteries are also frequently attacked by syphilis, which gives rise to inflammation and degeneration of their middle coats. Recent researches* go to prove that arterial aneurysms, other than those due to direct injury, occur almost solely in syphilitic patients.

PULMONARY ARTERY

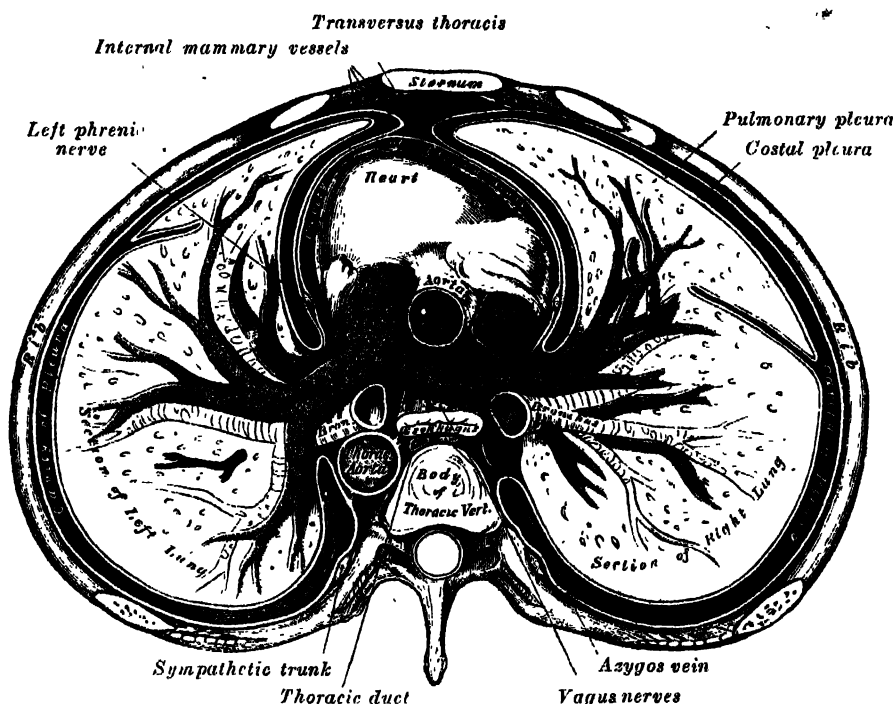
The **pulmonary artery** (figs. 612, 613) conveys venous blood from the right ventricle of the heart to the lungs. It is about 5 cm. in length and 3 cm. in diameter, and arises from the *conus arteriosus of the right ventricle*. It runs upwards and backwards, passing at first in front and then to the left of the ascending aorta, as far as the under surface of the aortic arch, where it divides, about the level of the fibrocartilage between the fifth and sixth thoracic vertebræ, into right and left branches of nearly equal size.

* C. U. Aitchison, *Arch. of the Pathological Institute of the London Hospital*, 1908, ii. p. 1.

Relations.—The whole of this vessel is contained within the pericardium. It is enclosed in a tube of the visceral layer of the serous pericardium, common to it and the ascending aorta. The fibrous layer of the pericardium is gradually lost upon the external coats of the two branches of the artery. In front, the pulmonary artery is separated from the anterior end of the second left intercostal space by the pleura, the left lung, and the pericardium; it rests at first upon the ascending aorta; higher up it lies in front of the left atrium, and the ascending aorta is on its right side. On either side of its origin is the auricle of the corresponding atrium, and a coronary artery; the left coronary artery, in the first part of its course passes behind the vessel. The superficial part of the cardiac plexus lies above its bifurcation, between it and the arch of the aorta.

The right branch of the pulmonary artery, longer and larger than the left, runs horizontally to the right, behind the ascending aorta, superior vena cava,

FIG. 612.—Diagram of a transverse section of thorax, showing relations of pulmonary artery, etc.



and upper right pulmonary vein, and in front of the right bronchus, to the root of the right lung, where it divides into two branches. The lower and larger of these is distributed to the middle and lower lobes of the lung; the upper and smaller accompanies the eparterial bronchus to the upper lobe.

The left branch of the pulmonary artery, a little shorter and smaller than the right, runs horizontally in front of the descending aorta and left bronchus to the root of the left lung, where it divides into two branches, one for either lobe of the lung. Above, it is united to the concavity of the aortic arch by the ligamentum arteriosum, on the left of which is the left recurrent nerve, and on the right the superficial part of the cardiac plexus. Below, it is joined to the upper left pulmonary vein by the ligament of the left vena cava (p. 552).

The terminal branches of the pulmonary arteries are described with the anatomy of the lungs.

Applied Anatomy.—Stenosis (narrowing) or atresia (non-perforation) of the pulmonary orifice, usually combined with other developmental anomalies such as defect of the upper part of the interventricular septum, patency of the ductus arteriosus, or patency of the

foramen ovale, is the commonest form of congenital heart disease. It is due to maldevelopment, and not to fetal endocarditis; possibly, as Keith suggests, to malformation of the bulbus cordis. In well-marked cases the child with congenital heart disease is cyanosed, short of breath on exertion, and puny, generally dying of sudden heart failure or bronchitis before adolescence. The chief signs of the condition are the loud, harsh systolic cardiac murmur best heard over the second left costal cartilage, cyanosis, clubbing of the finger-tips, and the presence of an excess of red corpuscles in the blood.

Embolism of the pulmonary artery by a clot of blood coming from the right side of the heart in patients with heart-disease, or from a thrombosed vein in cases, for example, of influenza, enteric fever, puerperal sepsis, or fractured limbs, is a common cause of sudden or rapid death. The patient may cry out with sudden excruciating pain in the precordia when the detached embolus lodges, and after a brief period of intense dyspnoea, pallor, and anguish, die.

THE AORTA

The **aorta** is the main trunk of a series of vessels which convey the oxygenated blood to the tissues of the body. It begins at the upper part of the left ventricle, where it is about 3 cm. in diameter, and after ascending for a short distance, arches backwards and to the left, over the root of the left lung; it then descends within the thorax on the left side of the vertebral column, passes into the abdominal cavity through the aortic hiatus in the Diaphragm, and ends, considerably diminished in size (about 1.75 cm. in diameter), opposite the left half of the lower border of the fourth lumbar vertebra, by dividing into the right and left common iliac arteries. Hence it is described in several portions, viz. the *ascending aorta*, the *arch of the aorta*, and the *descending aorta*, which last is divided into the *thoracic* and *abdominal aortae*.

ASCENDING AORTA

The **ascending aorta** (fig. 613) is about 5 cm. long. It begins at the upper part of the base of the left ventricle, on a level with the lower border of the third costal cartilage, behind the left half of the sternum; it passes obliquely upwards, forwards, and to the right, in the direction of the heart's axis, as high as the upper border of the second right costal cartilage, describing a slight curve in its course, and being situated behind the posterior surface of the sternum. At its origin it presents, opposite the segments of the aortic valve, three small dilatations called the aortic sinuses. At the union of the ascending aorta with the aortic arch the calibre of the vessel is slightly increased, owing to a bulging of its right wall. This dilatation is termed the *bulb of the aorta*, and on transverse section presents a somewhat oval figure.

Relations.—The ascending aorta is contained within the pericardium, and is enclosed in a tube of the serous pericardium, common to it and the pulmonary artery. It is covered at its commencement by the trunk of the pulmonary artery and the right auricle, and, higher up, is separated from the sternum by the pericardium, the right pleura, the anterior margin of the right lung, some loose areolar tissue, and the remains of the thymus; posterior to it are the left atrium, the right pulmonary artery, and the right bronchus. On its *right side* are the superior vena cava and right atrium, the former lying partly behind it; on its *left side* is the pulmonary artery.

Branches.—The branches of the ascending aorta are the right and left coronary arteries (figs. 601, 613) which supply the heart; they arise from the aortic sinuses immediately above the attached margins of the aortic semilunar valves.

✓ The **right coronary artery** arises from the anterior aortic sinus. It passes at first between the conus arteriosus and the right auricle and then runs in the right portion of the coronary sulcus, coursing on the front of the heart from left to right, and then on the diaphragmatic surface of the heart from right to left as far as the posterior longitudinal sulcus, down which it is continued to the apex of the heart as the *posterior descending branch*. It gives off a large *marginal branch* which follows the acute margin of the heart and ramifies on both surfaces of the right ventricle. It also supplies branches to the right atrium and to the part of the left ventricle which adjoins the posterior longitudinal sulcus.

✓ The **left coronary artery**, larger than the right, arises from the left posterior aortic sinus and divides into an anterior descending and a circumflex branch.

anterior descending branch passes at first behind the pulmonary artery and then comes forward between that vessel and the left auricle to reach the anterior longitudinal sulcus, along which it descends to the incisura apicis cordis; it gives branches to both ventricles. The *circumflex branch* follows the left part of the coronary sulcus, running first to the left and then to the right, reaching nearly as far as the posterior longitudinal sulcus; it gives branches to the left atrium and ventricle.

FIG. 613.—The arch of the aorta, and its branches

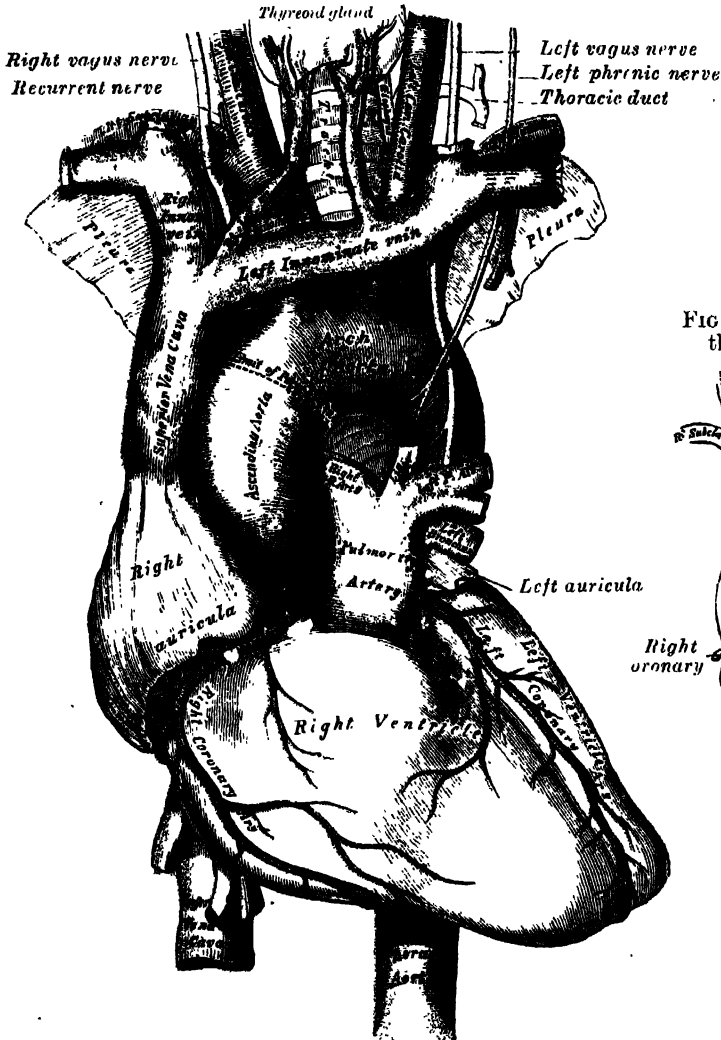
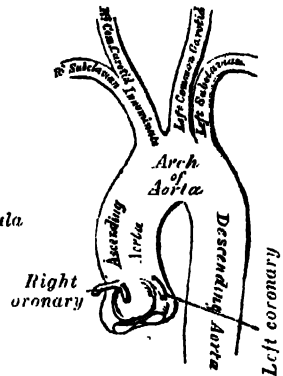


FIG. 614.—Plan of the branches.



There is a free anastomosis between the minute branches of the two coronary arteries in the substance of the heart.

Peculiarities.—The coronary arteries occasionally arise by a common trunk; their number may be increased to three or four.

Applied Anatomy.—The sudden blocking of a coronary artery by an embolus, or its more gradual obstruction by arterial disease or thrombosis, is a common cause of sudden death in persons past middle age. If the obstruction to the passage of blood is incomplete, true *angina pectoris* may occur. In this condition the patient is suddenly seized with a spasm of agonising pain in the precordial region and down the left arm, together with an indescribable sense of anguish. He may die in such an attack, or succumb a few hours or days later from heart failure, or survive a number of attacks.

ARCH OF THE AORTA

The **arch of the aorta** (fig. 613) connects the ascending with the descending aorta; it begins at the level of the upper border of the second right sternocostal articulation, and runs at first upwards, backwards, and to the left in front of the trachea; it is then directed backwards on the left side of the trachea, and finally passes downwards on the left side of the body of the fourth thoracic vertebra, at the lower border of which it is continuous with the descending aorta. It thus forms two curvatures: one with its convexity upwards, the other with its convexity forwards and to the left. Its upper border is usually about 2.5 cm. below the superior border of the manubrium sterni.

Relations.—The arch of the aorta is covered *anteriorly* by the pleuræ and anterior margins of the lungs, and by the remains of the thymus. As the vessel runs backwards its *left* side is in contact with the left lung and pleura. Passing downwards on the left side of this part of the arch are four nerves; in order from before backwards these are: the left phrenic, the lower of the superior cardiac branches of the left vagus, the superior cardiac branch of the left sympathetic, and the trunk of the left vagus. As the last nerve crosses the arch it gives off its recurrent branch which hooks round below the vessel and then passes upwards on its right side. The left superior intercostal vein runs obliquely upwards and forwards on the left side of the arch, between the phrenic and vagus nerves. On the *right* are the deep part of the cardiac plexus, the left recurrent nerve, the œsophagus, and the thoracic duct; the trachea lies behind and to the right of the vessel. *Above* are the innominate, left common carotid, and left subclavian arteries, which arise from the convexity of the arch and are crossed close to their origins by the left innominate vein. *Below* are the bifurcation of the pulmonary artery, the left bronchus, the ligamentum arteriosum, the superior part of the cardiac plexus, and the left recurrent nerve. As already stated, the ligamentum arteriosum connects the commencement of the left pulmonary artery to the aortic arch.

In the foetus the lumen of the aorta is considerably narrowed between the origin of the left subclavian artery and the attachment of the ligamentum arteriosum, forming what is termed the *aortic isthmus*, while immediately beyond the ductus arteriosus the vessel presents a fusiform dilatation which is termed the *aortic spindle*—the point of junction of the two parts being marked in the concavity of the arch by an indentation or angle. These conditions persist, to some extent, in the adult, where His found that the average diameter of the spindle exceeded that of the isthmus by 3 mm.

Peculiarities.—The summit of the arch of the aorta is usually about 2.5 cm. below the upper border of the sternum: but it may reach nearly to the top of the bone. Occasionally it is found 4 cm., more rarely from 5 to 8 cm., below this point. Sometimes the aorta arches over the root of the right lung (right aortic arch) instead of over that of the left, and passes down on the right side of the vertebral column, a condition which is found in birds. In such cases there is a transposition of the thoracic and of the abdominal viscera. Less frequently the aorta, after arching over the root of the right lung, is directed to its usual position on the left side of the vertebral column; this peculiarity is not accompanied by transposition of the viscera. The aorta occasionally divides, as in some quadrupeds, into an ascending and a descending trunk, the former of which is directed vertically upwards, and subdivides into three branches, to supply the head and upper extremities. Sometimes the aorta subdivides near its origin into two branches, which soon reunite; in one case of this kind the œsophagus and trachea passed through the interval between the two branches; this is the normal condition of the vessel in the reptilia.

Applied Anatomy.—Of all the vessels of the arterial system, the aorta, and more especially its arch, is most frequently the seat of disease; hence it is important to consider some of the consequences that may ensue from aneurysm of this part.

Aneurysm of the ascending aorta, in the situation of the aortic sinuses, in the great majority of cases, affects the anterior sinus; this is mainly owing to the fact that the regurgitation of blood upon the sinuses takes place chiefly on the anterior aspect of the vessel. As the aneurysmal sac enlarges, it may compress any or all of the structures in immediate proximity with it, but chiefly projects towards the right anterior side; and, consequently, interferes mainly with those structures that have a corresponding relation with the vessel. If it project forwards, it may destroy the sternum and the cartilages of the ribs, usually on the right side, and appear as a pulsating tumour on the front of the chest, just below the manubrium; or it may burst into the pericardium, or may compress, or open into the right lung, the trachea, bronchi, or œsophagus. In the majority

of cases it bursts into the cavity of the pericardium, the patient suddenly drops down dead, and upon a post-mortem examination, the pericardial sac is found full of blood; or it may compress the right atrium, or the pulmonary artery, and adjoining part of the right ventricle, and open into one or the other of these parts. It may press upon the superior vena cava or the innominate veins, causing great venous engorgement. The face becomes livid and swollen, the right arm and anterior thoracic wall oedematous, and the congestion of the brain gives rise to headache and vertigo. An aneurysm has occasionally perforated into the superior vena cava, setting up an arteriovenous aneurysm. When this happens the patient suddenly becomes very short of breath, intensely congested and oedematous in the face and upper part of the body, and develops a palpable thrill and a continuous humming murmur, loudest during systole, over the sternum. Death follows a few days or weeks after such a perforation; and somewhat similar symptoms are occasioned when an aortic aneurysm erodes and bursts into the pulmonary artery.

Regarding the arch of the aorta, the student is reminded that the vessel lies against the trachea, oesophagus, and thoracic duct; that the recurrent nerve winds around it; and that from its upper part are given off three large trunks, which supply the head, neck, and upper extremities. An aneurysmal tumour taking origin from the posterior part of the vessel, its most usual site, may press upon the trachea and give rise to the sign known as 'tracheal tugging,' impede the breathing, or produce cough, dyspnoea, bronchiectasis, hæmoptysis, or stridulous breathing, or it may ultimately burst into that tube, producing fatal hæmorrhage. Again, its pressure on the left recurrent nerve may give rise to symptoms of laryngeal paralysis; or it may press upon the thoracic duct and destroy life by inanition; or it may involve the oesophagus, producing dysphagia, and has not infrequently been mistaken for oesophageal stricture; or it may burst into the oesophagus, when fatal hæmorrhage will occur. Compression or stretching of the sympathetic filaments may, in the former case, produce dilatation of the pupil; in the latter, contraction, if the conducting power is abolished, on the affected side. This has proved to be an important diagnostic sign in this disease; it has also been attributed to lowering of the arterial pressure in the iris, which is dilated, the lowering being due to partial obstruction of the orifice of the innominate artery on the right side, or of the common carotid on the left, as the case may be, by aneurysmal deformation of the aortic arch at the point where these vessels arise. Again, the innominate artery, or the subclavian, or left carotid, may be so obstructed by clots as to produce a weakness, or even a disappearance, of the pulse in one or the other wrist, or in the left superficial temporal artery; or the tumour may present itself at or above the manubrium, generally either in the median line, or to the right of the sternum, and may simulate an aneurysm of one of the arteries of the neck.

Many of the physical signs of an aortic aneurysm may be simulated with extraordinary fidelity by the preternatural pulsation or throbbing of a distended and elastic aorta, when no true aneurysmal dilatation exists. This condition may be met with in young persons with aortic reflux and greatly hypertrophied hearts, in patients who are of a neurotic or hysterical temperament, and in cases of Graves's disease or of marked anæmia. The condition is known as dynamic dilatation of the aorta, and in no way threatens life.

Branches (figs. 613, 614).—Three branches are given off from the summit of the arch of the aorta, viz.: the innominate, the left common carotid, and the left subclavian.

Peculiarities.—The branches may spring from the commencement of the arch or upper part of the ascending aorta; or the distance between them at their origins may be increased or diminished, the most frequent change in this respect being the approximation of the left carotid to the innominate artery.

The number of the primary branches may be reduced to one; more commonly there are two, the left carotid arising from the innominate artery, or (more rarely) the carotid and subclavian arteries of the left side arising from a left innominate artery. But the number may be increased to four, through the right carotid and subclavian arteries arising directly from the aorta; in most of these cases the right subclavian arises from the left end of the arch; in other cases it is the second or third branch given off. Another common variation in which there are four primary branches is that where the left vertebral artery arises from the arch of the aorta between the left carotid and subclavian arteries. Lastly, the number of trunks may be increased to five or six; in these instances, the external and internal carotid arteries arise separately, the common carotid being absent on one or both sides. In some few cases six branches have been found, and this condition is associated with the origin of both vertebral arteries from the arch.

When the aorta arches over to the right side, the three branches have an arrangement the reverse of what is usual: there is a left innominate artery, and the right carotid and right subclavian arise separately. In other cases, where the aorta takes its usual course, the two carotids may be joined in a common trunk, and the subclavians arise separately from the arch, the right subclavian generally arising from the left end of the arch.

Other arteries may spring from the arch of the aorta. Of these the most common are the bronchial, one or both, and the thyroidea ima; the internal mammary and the inferior thyreoid have been seen to arise from it.

INNOMINATE ARTERY (fig. 613)

The innominate artery (*arteria anonyma*) is the largest branch of the arch of the aorta, and is from 4 to 5 cm. in length. It arises from the convexity of the arch of the aorta, posterior to the centre of the manubrium sterni; it passes obliquely upwards, backwards, and to the right to the level of the upper border of the right sternoclavicular articulation, where it divides into the right common carotid and right subclavian arteries.

Relations.—*Anteriorly*, it is separated from the manubrium sterni by the Sternohyoideus and Sternothyroideus, the remains of the thymus, the left innominate and right inferior thyroid veins which cross its root, and sometimes the superior cardiac branches of the right vagus nerve. *Posterior* to it is the trachea, which it crosses obliquely. On the *right side* are the right vagus nerve, the right innominate vein, the superior vena cava, the right phrenic nerve, and the pleura; and on the *left side*, the remains of the thymus, the origin of the left common carotid artery, the inferior thyroid veins, and the trachea.

Branches.—The innominate artery is usually devoid of branches, but occasionally a small one, the *thyroidea ima*, arises from it, and sometimes it gives off a *thymic* or a *bronchial branch*.

The *thyroidea ima* ascends in front of the trachea to the lower part of the thyroid gland, which it supplies. It varies greatly in size, and appears to compensate for deficiency or absence of one of the other thyroid vessels. It occasionally arises from the aorta, the right common carotid, the subclavian or the internal mammary.

Peculiarities.—The innominate artery sometimes divides above the level of the sternoclavicular joint, less frequently below it. When the aortic arch is on the right side, the innominate artery is directed to the left side of the neck.

Applied Anatomy.—Aneurysm of the innominate artery not infrequently occurs as an accompaniment to aneurysm of the arch of the aorta. It causes bulging of the right sternoclavicular articulation, pushing forwards the Sternocleidomastoideus muscle and filling up the jugular notch. It produces serious pressure symptoms: from pressure on the innominate veins it may cause oedema of the upper extremities, and of the head and neck; from pressure on the trachea it produces dyspnoea; and from pressure on the right recurrent nerve, hoarseness and laryngeal cough.

Although the operation of tying the innominate artery has been performed by several surgeons, few successes have been recorded. The chief danger of the operation appears to be the frequency of secondary hemorrhage; but in the present day, with the practice of aseptic surgery and our greater knowledge of the use of the ligature, more favourable results may be anticipated. The main obstacles to the operation are the deep situation of the artery behind the sternum and the number of important structures which surround it.

In order to apply a ligature to this vessel, the patient is to be placed upon his back with the thorax slightly raised, the head bent a little backwards, and the right shoulder strongly depressed, so as to draw out the artery from behind the sternum into the neck. An incision 7 cm. or more in length is then made along the anterior border of the Sternocleidomastoideus, terminating at the sternal end of the clavicle. From this point, a second incision is carried about the same length along the upper border of the clavicle. The skin is then dissected back, and the Platysma divided: the sternal end of the Sternocleidomastoideus is now brought into view, and a director being passed beneath it, and close to its deep surface so as to avoid any small vessels, it is to be divided: in like manner the clavicular origin is to be divided throughout the whole or greater part of its attachment. By pressing aside any loose cellular tissue or vessels that may now appear, the Sternohyoideus and Sternothyroideus muscles will be exposed, and must be divided. The inferior thyroid veins may come into view, and must be carefully drawn either upwards or downwards, by means of a blunt hook, or tied with double ligatures and divided. After tearing through a strong fibrocellular lamina, the right common carotid is brought into view, and being traced downwards, the innominate artery is reached. The left innominate vein should now be depressed; the right innominate vein, the internal jugular vein, and the vagus nerve drawn to the right side: and a curved aneurysm needle may then be passed around the vessel, close to its surface, and in a direction from below upwards and medially; care being taken to avoid the right pleural sac, the trachea, and cardiac nerves. The ligature should be applied to the artery as high as possible, in order to allow room between it and the aorta for the formation of the coagulum. The importance of avoiding the thyroid plexus of veins during the primary steps of the operation, and the pleural sac while including the vessel in the ligature, should be most carefully borne in mind.

Collateral Circulation.—Allan Burns demonstrated, on the dead subject, the possibility of the establishment of the collateral circulation after ligature of the innominate

artery, by tying and dividing that artery. He then found that 'Even coarse injection, impelled into the aorta, passed freely by the anastomosing branches into the arteries of the right arm, filling them and all the vessels of the head completely.'* The branches by which this circulation is carried on are numerous; thus, all the communications across the middle line between the branches of the carotid arteries of opposite sides are available for the supply of blood to the right side of the head and neck; the anastomosis between the costocervical of the subclavian and the first aortic intercostal (see *infra* on the collateral circulation after obliteration of the thoracic aorta) brings the blood, by a free and direct course, into the right subclavian; the numerous connexions between the intercostal arteries and the branches of the axillary and internal mammary arteries assist in the supply of blood to the right arm, while the inferior epigastric from the external iliac, by means of its anastomosis with the internal mammary, compensates for any deficiency in the vascularity of the wall of the chest.

ARTERIES OF THE HEAD AND NECK

The principal arteries of the head and neck are the two common carotids; they ascend in the neck and each divides into two branches, viz. (1) the external carotid, supplying the exterior of the head, the face, and the greater part of the neck; (2) the internal carotid, supplying to a great extent the parts within the cranial and orbital cavities.

COMMON CAROTID ARTERIES

The common carotid arteries differ in length and in their mode of origin. The *right* begins at the bifurcation of the innominate artery behind the sternoclavicular joint and is confined to the neck. The *left* springs from the highest part of the arch of the aorta to the left of, and on a plane posterior to, the innominate artery, and therefore consists of a thoracic and a cervical portion.

The thoracic portion of the left common carotid artery ascends from the arch of the aorta through the superior mediastinal cavity to the level of the left sternoclavicular joint, where it is continuous with the cervical portion.

Relations.—*In front*, it is separated from the manubrium sterni by the Sternohyoideus and Sternothyreoideus, the anterior portions of the left pleura and lung, the left innominate vein, and the remains of the thymus; *behind* it are the trachea, œsophagus, left recurrent nerve, and thoracic duct. To its *right side* below, is the innominate artery, and above, the trachea, the inferior thyroid veins, and the remains of the thymus, to its *left side* are the left vagus and phrenic nerves, the left pleura and lung. The left subclavian artery is posterior and slightly lateral to it.

The cervical portions of the common carotid arteries resemble each other so closely that one description will apply to both (fig. 615). Each passes obliquely upwards, from behind the sternoclavicular articulation, to the level of the upper border of the thyroid cartilage, where it divides into the external and internal carotid arteries. Behind the point of division of the artery is a small reddish brown, ductless gland, termed the *glomus caroticum* (carotid body).

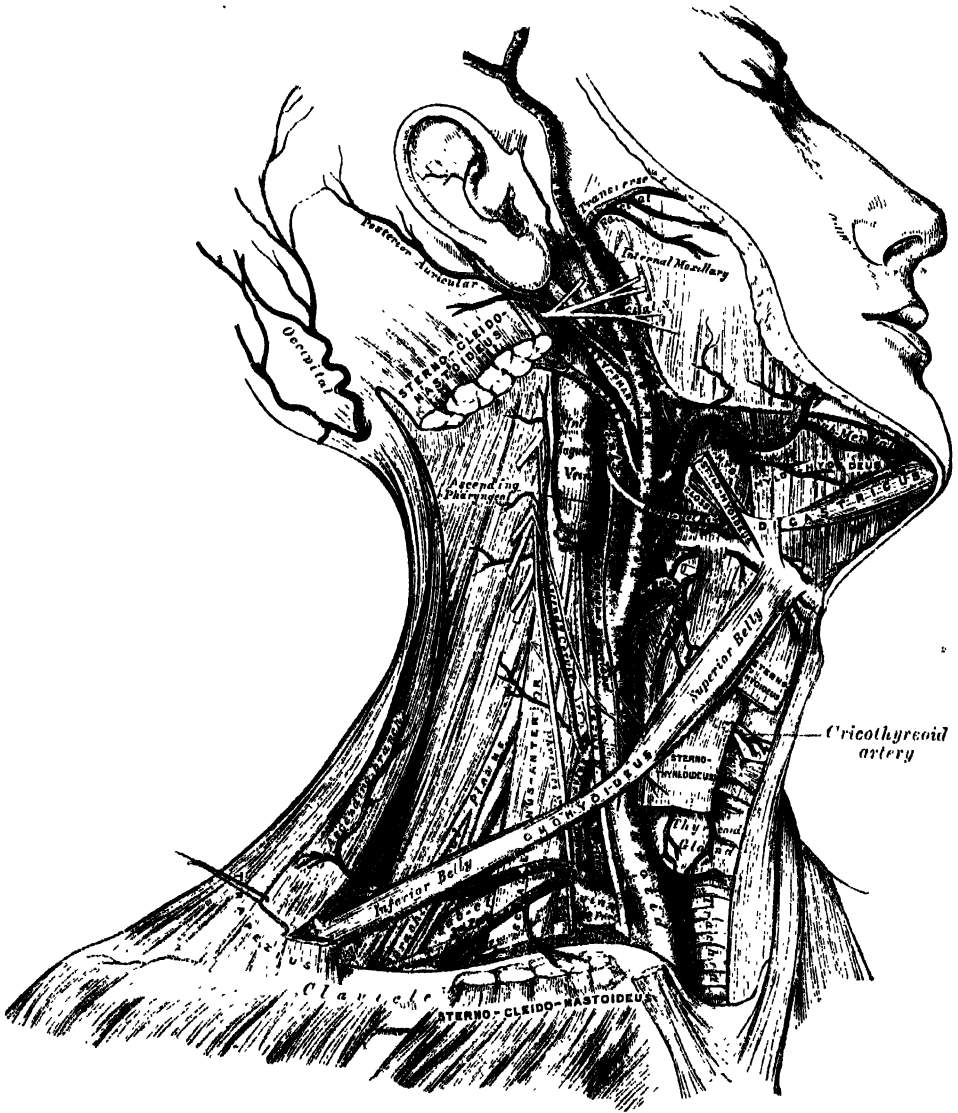
At the lower part of the neck the two arteries are separated from each other by a very narrow interval which contains the trachea; but at the upper part, the thyroid gland, the larynx, and the pharynx project forwards between the two vessels. The common carotid artery is contained in a sheath, which is derived from the fascia colli (deep cervical fascia) and encloses also the internal jugular vein and vagus nerve, the vein lying lateral to the artery, and the nerve between the artery and vein, on a plane posterior to both. In the sheath, each of these structures has a separate fibrous investment.

Relations.—At the lower part of the neck the common carotid artery is very deeply seated, being covered by the integument, superficial fascia, Platysma, deep cervical fascia, and the Sternocleidomastoideus, Sternohyoideus, Sternothyreoideus, and Omohyoideus; in the upper part of its course it is more superficial, being covered merely by the integument, the superficial fascia, Platysma, deep

* *Surgical Anatomy of the Head and Neck*, p. 62.

cervical fascia, and the medial margin of the Sternocleidomastoideus. When the latter muscle is drawn backwards, the artery is seen to be contained in a triangular space, the *carotid triangle*, bounded behind by the Sternocleidomastoideus, above by the Stylohyoideus and posterior belly of the Digastricus, and below by the superior belly of the Omohyoideus. This part of the artery is crossed obliquely, from its medial to its lateral side, by the sternocleidomastoid branch of the superior

FIG. 615.—Superficial dissection of the right side of the neck, showing the carotid and subclavian arteries.



thyroid artery. In front of its sheath is the descending branch of the hypoglossal nerve, this branch being joined by the descendens cervicalis nerve which springs from the second and third cervical nerves and crosses the vessel obliquely: sometimes the descending branch of the hypoglossal nerve is contained within the sheath of the vessels. The superior thyroid vein crosses the artery near its termination, and the middle thyroid vein a little below the level of the cricoid cartilage: the anterior jugular vein crosses the artery just above the clavicle, but is separated from it by the Sternohyoideus and Sternothyroideus. *Behind* the artery is separated from the transverse processes of the cervical vertebrae by the Longus

colli and Longus capitis, the sympathetic trunk being interposed between the artery and the muscles. The inferior thyroid artery crosses behind the lower part of the vessel; below the level of the sixth cervical vertebra the left common carotid artery is in relation posteriorly with the vertebral artery and the cervical part of the thoracic duct. *Medially*, it is in relation with the œsophagus, trachea, and thyroid gland (which overlaps it), the inferior thyroid artery and recurrent nerve being interposed; higher up, with the larynx and pharynx. *Lateral* to the artery are the internal jugular vein and vagus nerve.

At the lower part of the neck, the right recurrent nerve crosses obliquely behind the artery; the right internal jugular vein diverges from the artery, but the left approaches and often overlaps the lower part of the artery.

Peculiarities.—In about 12 per cent. of cases the *right common carotid* arises above the level of the upper border of the sternoclavicular articulation. It may arise as a separate branch from the arch of the aorta, or in conjunction with the left carotid. The *left common carotid* varies in its origin more frequently than the right. In the majority of abnormal cases it arises with the innominate artery; if that artery be absent, the two carotids arise usually by a single trunk. It is rarely joined with the left subclavian, except in cases of transposition of the aortic arch.

Division of the artery may occur at or above the level of the hyoid bone; more rarely it occurs below the usual level, opposite the middle of the larynx, or the lower border of the cricoid cartilage; one case is related by Morgagni, where the artery was only 4 cm. in length and divided at the root of the neck. Very rarely, the common carotid ascends in the neck without undergoing subdivision, either the external or the internal carotid being wanting. In a few cases the common carotid has been found to be absent, the external and internal carotids arising directly from the arch of the aorta; this peculiarity existed on both sides in some instances, on one side only in others.

The common carotid usually supplies no branch previous to its bifurcation; but it may give origin to the vertebral, the superior thyroid or its laryngeal branch, the ascending pharyngeal, the inferior thyroid, or the occipital.

Applied Anatomy.—Aneurysms are not commonly met with on the common carotid; when they do occur they are usually situated low down at the root of the neck, or just below the point of bifurcation of the vessel. They do not often assume a large size, and are more commonly found on the right side. As they increase in size they displace the trachea and larynx, and therefore dyspnoea becomes a prominent symptom. Dysphagia also may be present from pressure on the œsophagus, especially if the aneurysm is on the left side; and pressure on the recurrent nerve may produce hoarseness and laryngeal cough. Pressure on the sympathetic will cause pupillary changes—dilatation of the pupil when the sympathetic is irritated or the arterial blood-supply to the eye is lessened, contraction when the sympathetic has become paralysed; sympathetic irritation may also cause unilateral sweating of the head and neck. Pressure on the superficial branches of the cervical plexus may give rise to pain in the head, face, and neck; pressure on the vagus to irregular action of the heart and to asthmatic attacks. It is important to bear in mind that an enlarged lymph gland in the superior carotid triangle, receiving a transmitted pulsation from the carotid artery, may simulate aneurysm of that vessel, but may be distinguished from it by the character of the pulsation, which is not expansile.

Embolism of the left common carotid artery, or the thrombosis that may follow injury to the wall of the vessel by penetrating gunshot wounds of the neck, have been known to produce aphasia by interference with the blood-supply of the brain.

Digital compression of the common carotid is sometimes required, and is best effected by compressing the vessel with the thumb against the anterior tubercle of the transverse process of the sixth cervical vertebra (p. 164).

Ligature of the common carotid artery may be necessary in a case of wound of that vessel or its branches, in aneurysm, or in a case of pulsating tumour of the orbit or skull. If the wound involves the trunk of the common carotid, it will be necessary to tie the artery above and below the wounded part. In cases of aneurysm, the whole of the artery is accessible, and any part of it may be tied. When the case is such as to allow of a choice being made, the upper part of the carotid should be selected as the spot upon which to place a ligature, for the lower part of the vessel is placed very deeply in the neck, and covered by three layers of muscles; moreover, on the left side, the internal jugular vein, in the great majority of cases, passes obliquely in front of it. The part of the vessel which is most favourable for the operation is that opposite the level of the cricoid cartilage. It occasionally happens that the carotid artery bifurcates below its usual position: if the artery be exposed at its point of bifurcation, both divisions of the vessel should be tied near their origin, in preference to tying the trunk of the artery near its termination; and if, in consequence of the entire absence of the common carotid, or from its early division, two arteries, the external and internal carotids, are met with, the ligature should be placed on that vessel which is found on compression to be connected with the diseased area.

In this operation, the direction of the vessel and the anterior margin of the Sternocleidomastoideus are the chief guides to its performance. The patient should be placed

on his back with the head extended and turned slightly to the opposite side: an incision is to be made, 7 or 8 cm. long, in the direction of the anterior border of the Sternocleidomastoideus, so that the centre corresponds to the level of the cricoid cartilage. After dividing the integument, superficial fascia, Platysma, and deep fascia, the margins of the wound are held asunder by retractors, and the ramus descendens hypoglossi is now exposed, and must be avoided. The sheath of the vessel is to be raised by forceps, and opened to a small extent over the artery at its medial side. The internal jugular vein may present itself alternately distended and relaxed, and must be carefully avoided. The aneurysm needle is passed from the lateral aspect, care being taken to keep the needle in close contact with the artery, and thus avoid the risk of injuring the internal jugular vein, or including the vagus nerve. Before the ligature is tied, it should be ascertained that nothing but the artery is included in it.

Ligature of the common carotid near the root of the neck is sometimes required in cases of aneurysm of the upper part of the artery, especially if the sac is of large size. It is best performed by dividing the sternal origin of the Sternocleidomastoideus, but may be done in some cases, if the aneurysm is not of very large size, by an incision along the anterior border of the muscle, extending down to the sternoclavicular articulation, and by then retracting the muscle. Beneath it are two additional muscular layers, viz.: the Sternohyoideus and the Sternothyroideus; these have to be split and retracted, one after the other, before the sheath of the vessel is reached. In doing this, care must be taken not to wound the anterior jugular vein, which crosses the Sternohyoideus to reach the external jugular or subclavian vein. The sheath must be opened on its medial or tracheal side, so as to avoid the internal jugular vein. Special care is necessary on the left side, where the artery is commonly overlapped by the vein; on the right side there is usually an interval between the artery and the vein, and the risk of wounding the latter is less.

The common carotid artery, being a long vessel without any branches, is particularly suitable for the performance of Brasdor's operation for the cure of an aneurysm of the lower part of the vessel. Brasdor's procedure consists in ligaturing the artery on the distal side of the aneurysm, and in the case of the common carotid there are no branches given off from the vessel between the aneurysm and the site of the ligature; hence the flow of blood through the sac of the aneurysm is diminished, and cure takes place in the usual way by the deposit of laminated fibrin.

Collateral Circulation.—After ligature of the common carotid, the collateral circulation can be perfectly established by the free communication which exists between the carotid arteries of opposite sides, both without and within the cranium, and by enlargement of the branches of the subclavian artery. The chief communications outside the skull take place between the superior and inferior thyroid arteries, and between the profunda cervicis and ramus descendens of the occipital: the vertebral takes the place of the internal carotid within the cranium.

EXTERNAL CAROTID ARTERY

The **external carotid artery** (fig. 615) begins opposite the upper border of the thyroid cartilage, at the level of the disc between the third and fourth cervical vertebræ, and, taking a slightly curved course, passes upwards and forwards, and then inclines backwards to a point behind the neck of the mandible, where it divides into the superficial temporal and internal maxillary arteries. It diminishes rapidly in size, owing to the number and large size of the branches given off from it. In the child, it is somewhat smaller than the internal carotid; but in the adult, the two vessels are of nearly equal size. At its origin, this artery is more superficial, and placed nearer the middle line than the internal carotid artery, and is contained within the carotid triangle.

Relations.—The external carotid artery is covered by the skin, superficial fascia, Platysma, deep fascia, and anterior margin of the Sternocleidomastoideus; it is crossed by the Digastricus and Stylohyoideus, the hypoglossal nerve, the lingual, ranine and common facial veins, and sometimes by the superior thyroid veins; higher up it passes into the substance of the parotid gland, where it lies deep to the facial nerve and the junction of the superficial temporal and internal maxillary veins. Medial to it are the hyoid bone, the wall of the pharynx, the superior laryngeal nerve, and a portion of the parotid gland. Lateral to it, in the lower part of its course, is the internal carotid artery. It is separated from the internal carotid by the Styloglossus and Stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, and part of the parotid gland.

Applied Anatomy.—Ligature of the external carotid may be required in cases of wound of this vessel, or of its branches when these cannot be tied, and in some cases of pulsating tumours of the scalp or face. It is also done as a preliminary measure to

excision of the maxilla. The seat of election for ligature is between the origins of its superior thyroid and lingual branches, about a finger's breadth below the tip of the greater cornu of the hyoid bone. To tie the vessel, an incision is made from the angle of the mandible to the upper border of the thyroid cartilage, and the superficial tissues and the deep fascia divided. The anterior border of the Sternocleidomastoideus must be retracted and the lower border of the parotid gland raised, so as to expose the tendon of the Digastricus and the hypoglossal nerve, which cross the artery. The great difficulty in doing this is due to the plexus of veins derived from the superior thyroid and lingual veins, which overlie the artery: if necessary, these must be ligatured and divided. Care must be taken not to mistake the lingual and external maxillary arteries, when they arise by a common trunk, as they sometimes do, for the external carotid artery. The needle is to be passed from the lateral to the medial side of the vessel, carefully avoiding the superior laryngeal nerve, which lies in close proximity to the artery.

Collateral Circulation.—The circulation is re-established by the free communication between most of the large branches of the artery (external maxillary, lingual, superior thyroid, occipital) and the corresponding arteries of the opposite side, and by the anastomosis of its branches with those of the internal carotid artery, and of the occipital artery with branches of the subclavian, &c.

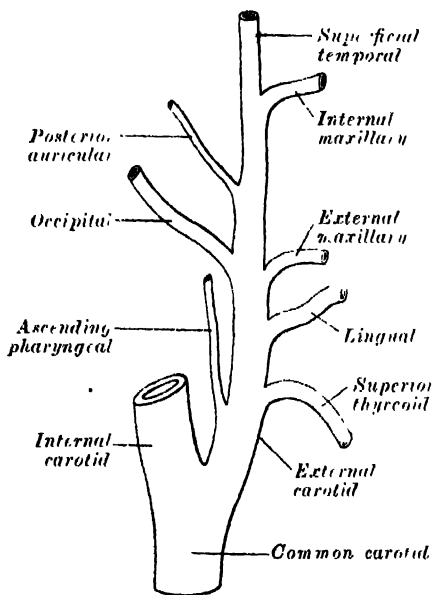
BRANCHES OF THE EXTERNAL CAROTID ARTERY (fig. 616)

The branches of the external carotid artery are :

- | | | |
|--------------------------|-------------------------|--------------------------|
| 1. Superior thyroid. | 4. External maxillary. | 7. Superficial temporal. |
| 2. Ascending pharyngeal. | 5. Occipital. | 8. Internal maxillary. |
| 3. Lingual. | 6. Posterior auricular. | |

1. The **superior thyroid artery** (fig. 615) arises from the external carotid artery just below the level of the greater cornu of the hyoid bone and ends in the thyroid gland.

FIG. 616.—Plan of the branches of the external carotid artery.



Relations.—From its origin beneath the anterior border of the Sternocleidomastoideus it runs upwards and forwards for a short distance in the carotid triangle, where it is covered by the skin, Platysma, and fascia; it then arches downwards beneath the Omohyoideus, Sternohyoideus, and Sternothyroideus. To its medial side are the Constrictor pharyngis inferior and the external branch of the superior laryngeal nerve.

Branches.—It distributes twigs to the adjacent muscles, and branches to the thyroid gland; it anastomoses with its fellow of the opposite side, and with the inferior thyroid arteries. The branches to the gland are generally two in number, an anterior and a posterior; the anterior and larger branch supplies principally the anterior surface; on the isthmus of the gland it anastomoses with the corresponding artery of the opposite side; the posterior branch descends on the posterior surface of the gland and anastomoses with the inferior thyroid artery.

Besides the arteries distributed to the muscles and to the thyroid gland, the superior thyroid artery supplies the following branches :

- | | |
|----------------------|---------------------|
| Hyoid. | Superior laryngeal. |
| Sternocleidomastoid. | Cricothyroid. |

The **hyoid branch** is small and runs along the lower border of the hyoid bone beneath the Thyrohyoideus and anastomoses with the vessel of the opposite side.

The **sternocleidomastoid branch** runs downwards and lateralwards across the sheath of the common carotid artery, and enters the Sternocleidomastoideus muscle; it frequently arises as a separate branch from the external carotid artery.

The **superior laryngeal artery**, larger than either of the preceding, accompanies the internal laryngeal branch of the superior laryngeal nerve, beneath the Thyro-hyoideus; it pierces the hyothyroid membrane, and supplies the muscles, mucous membrane and glands of the larynx, anastomosing with the artery of the opposite side, and with the inferior laryngeal branch of the inferior thyroid artery.

The **cricothyroid branch** is small and runs transversely across the cricothyroid membrane, communicating with the artery of the opposite side.

Applied Anatomy.—The superior thyroid, or one of its branches, is often divided in cases of cut throat, giving rise to considerable hæmorrhage. In such cases, the artery should be secured, the wound being enlarged for that purpose, if necessary. The operation may be easily performed, the artery being very superficial, and the only structures of importance covering it being a few small veins. The superior thyroid artery has been ligatured in cases of bronchocele, but the collateral circulation between this vessel and the artery of the opposite side, and the inferior thyroid, is so free that the operation has been given up, especially as better results are obtained by other means.

The position of the sternocleidomastoid branch is of importance in connexion with the operation of ligature of the common carotid artery. It crosses and lies on the sheath of this vessel and may chance to be wounded in opening the sheath. The position of the cricothyroid branch should be remembered, as it may prove the source of troublesome hæmorrhage during the operation of laryngotomy.

2. The **ascending pharyngeal artery** (fig. 621), the smallest branch of the external carotid artery, is a long slender vessel, deeply seated in the neck. It arises close to the origin of the external carotid, and ascends vertically between the internal carotid and the side of the pharynx to the under surface of the base of the skull, lying on the Longus capitis; it anastomoses freely with the ascending palatine branch of the external maxillary artery.

Its branches are :

Pharyngeal.

Posterior meningeal.

Inferior tympanic.

The **pharyngeal branches** are three or four in number. Two of these descend to supply the Constrictores pharyngis medius and inferior and the Stylopharyngeus, ramifying in their substance and in the mucous membrane lining them. A branch of variable size is distributed to the palate, and may take the place of the ascending palatine branch of the external maxillary artery, when that vessel is small. It passes inwards upon the Constrictor pharyngis superior, sends branches to the soft palate and tonsil, and supplies a twig to the auditory tube.

The **inferior tympanic artery** is a small branch which passes through the inferior tympanic canaliculus of the temporal bone, in company with the tympanic branch of the glossopharyngeal nerve, to supply the medial wall of the tympanic cavity and anastomose with the other tympanic arteries.

The **meningeal branches** are several small vessels which supply the dura mater. One, the *posterior meningeal*, enters the cranium through the jugular foramen; a second passes through the foramen lacerum; and occasionally a third through the canal for the hypoglossal nerve.

Numerous small vessels supply the Longi capitis and colli, the sympathetic trunk, the hypoglossal and vagus nerves, and the lymph-glands; they anastomose with the ascending cervical and vertebral arteries.

Applied Anatomy.—The ascending pharyngeal artery has been wounded from the throat; in one case the stem of a tobacco-pipe was driven into the vessel and caused fatal hæmorrhage.

3. The **lingual artery** (fig. 621) arises from the external carotid between the superior thyroid and external maxillary; it first runs obliquely upwards and medialwards to the greater cornu of the hyoid bone; it then curves downwards and forwards, forming a loop which is crossed by the hypoglossal nerve, and passing beneath the Digastricus and Stylohyoideus, it runs horizontally forwards, beneath the Hyoglossus, and finally, ascending almost perpendicularly to the tongue, it turns forwards on its lower surface as far as the tip.

Relations.—Its first portion is superficial, and is contained within the carotid triangle; it rests upon the Constrictor pharyngis medius, and is covered by the Platysma and the fascia of the neck. Its second portion also lies upon the

Constrictor pharyngis medius, being covered at first by the tendon of the Digastricus and by the Stylohyoideus, and afterwards by the Hyoglossus. Its third portion lies between the Hyoglossus and Genioglossus. The fourth or terminal part, under the name of the *arteria profunda linguæ* (ranine artery), runs along the inferior surface of the tongue to its tip, covered only by the mucous membrane; above it is the Longitudinalis inferior, and medial to it the Genioglossus. The hypoglossal nerve crosses the first part of the lingual artery, but is separated from the second part by the Hyoglossus.

The branches of the lingual artery are :

Hyoid.

Rami dorsales linguæ.

Sublingual.

A. profunda linguæ.

The **hyoid branch** runs along the upper border of the hyoid bone, supplying the muscles attached to it and anastomosing with its fellow of the opposite side.

The **rami dorsales linguæ** consist usually of two or three small branches; they arise beneath the Hyoglossus, ascend to the posterior part of the dorsum of the tongue, and supply its mucous membrane, the glossopalatine arch, the tonsil, soft palate, and epiglottis; they anastomose with the vessels of the opposite side.

The **sublingual artery** arises at the anterior margin of the Hyoglossus, and runs forward between the Genioglossus and Mylohyoideus to the sublingual gland. It supplies the gland and gives branches to the Mylohyoideus and neighbouring muscles, and to the mucous membrane of the mouth and gums. One branch runs behind the alveolar part of the mandible in the substance of the gum to anastomose with a similar artery from the other side; another pierces the Mylohyoideus and anastomoses with the submental branch of the external maxillary artery.

The **arteria profunda linguæ** (ranine artery) is the terminal portion of the lingual artery; it pursues a tortuous course and runs along the under surface of the tongue at the side of the frenulum linguæ, below the Longitudinalis inferior, and above the mucous membrane; it lies on the lateral side of the Genioglossus, accompanied by the lingual nerve.

Applied Anatomy.—The lingual artery is not infrequently divided near its origin in cases of cut throat; while severe hæmorrhage, which cannot be restrained by ordinary means, may ensue from a wound, or deep ulcer, of the tongue. In the former case, the primary wound may be enlarged if necessary, and the bleeding vessel secured; in the latter, it has been suggested that the lingual artery should be tied near its origin.

Ligature of the lingual artery has been practised occasionally as a preliminary measure to removal of the tongue. The operation is a difficult one on account of the depth of the artery, the number of important parts by which it is surrounded, and its occasional irregularity of origin. An incision is to be made in a curved direction from a finger's breadth behind the symphysis menti downwards to the cornu of the hyoid bone, and then upwards to near the angle of the mandible. Care must be taken not to carry this incision too far backwards, for fear of endangering the anterior facial vein. In the first incision the skin, superficial fascia, and Platysma will be divided, and the deep fascia displayed. This is then to be incised and the submaxillary gland exposed and pulled upwards. A triangular space is now seen, bounded in front by the posterior border of the Mylohyoideus, below and behind by the tendon of the Digastricus, and above by the hypoglossal nerve. The floor of the space is formed by the Hyoglossus, beneath which the artery lies. The parts are to be drawn forwards by a blunt hook inserted beneath the tendon of the Digastricus, and the fibres of the Hyoglossus cut through horizontally just above the Digastricus. The artery will then be exposed; and in passing the aneurysm needle, care must be taken not to open the pharynx. The hypoglossal nerve must also be avoided.

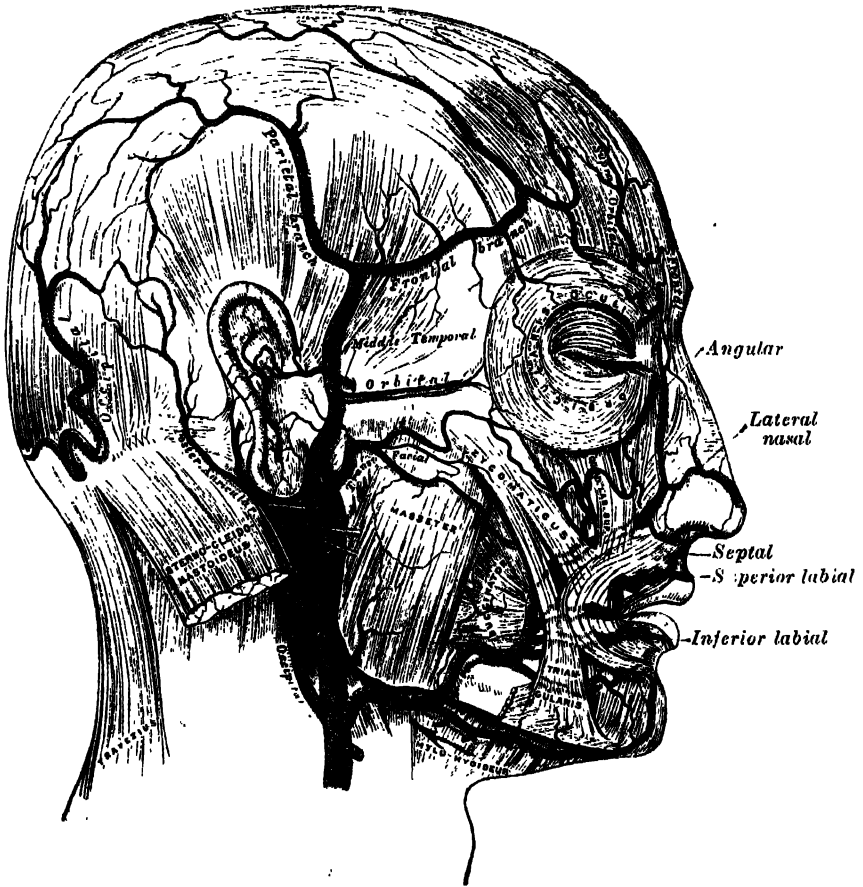
Troublesome hæmorrhage may occur in the division of the frenulum linguæ in children, if the aa. profundæ linguæ, which lie one on either side of it, be wounded. The operation should always be performed with a pair of blunt-pointed scissors, and the mucous membrane alone divided by a very superficial cut, which cannot endanger any vessel. Any further liberation of the tongue which may be necessary can be effected by tearing.

4. The **external maxillary artery** (facial artery) (fig. 617) arises in the carotid triangle a little above the lingual artery, and sheltered by the ramus of the mandible, passes obliquely up beneath the Digastricus and Stylohyoideus, over which it arches to enter a groove on the posterior border of the submaxillary gland. It then curves upwards over the body of the mandible at the anteroinferior angle of the Masseter; passes forwards and upwards across the cheek to the angle of the mouth, then ascends along the side of the nose,

and ends at the medial palpebral commissure, under the name of the *angular artery*. The external maxillary artery is remarkably tortuous: in the neck to accommodate itself to the movements of the pharynx during deglutition, and on the face to the movements of the mandible, lips, and cheeks.

Relations.—*In the neck*, its origin is superficial, being covered by the integument, Platysma, and fascia; it then passes beneath the Digastricus and Stylohyoideus muscles and part of the submaxillary gland, and frequently beneath the hypoglossal nerve. It lies upon the Constrictores pharyngis medius and superior, the latter of which separates it, at the summit of its arch, from the lower and posterior part of the tonsil. *On the face*, where it passes over the body of the mandible, it is

FIG. 617.—The arteries of the face and scalp.



comparatively superficial, lying immediately beneath the Platysma. In its course over the face, it is covered by the integument, the fat of the cheek, and, near the angle of the mouth, by the Platysma, Risorius, and Zygomaticus. It rests on the Buccinator and Caninus, and passes either over or under the infraorbital head of the Quadratus labii superioris. The anterior facial vein lies posterior to the artery, and takes a more direct course across the face, where it is separated from the artery by a considerable interval; in the neck it lies superficial to the artery. The branches of the facial nerve cross the artery from behind forwards.

The branches of the external maxillary artery may be divided into two sets: those given off in the neck (cervical), and those on the face (facial).

Cervical branches.

Ascending palatine.
Tonsillar.
Glandular.
Submental.

Facial branches.

Inferior labial.
Superior labial.
Lateral nasal.
Angular.

The **ascending palatine artery** (fig. 621) arises close to the origin of the external maxillary artery and passes up between the Styloglossus and Stylopharyngeus to the side of the pharynx, along which it is continued between the Constrictor pharyngis superior and the Pterygoideus internus towards the base of the skull. Near the Levator veli palatini it divides into two branches: one follows the course of this muscle, and, winding over the upper border of the Constrictor pharyngis superior, supplies the soft palate and the palatine glands, anastomosing with its fellow of the opposite side and with the descending palatine branch of the internal maxillary artery; the other pierces the Constrictor pharyngis superior and supplies the palatine tonsil and auditory tube, anastomosing with the tonsillar and ascending pharyngeal arteries.

The **tonsillar branch** (fig. 621) ascends between the Pterygoideus internus and Styloglossus, and then along the side of the pharynx; it perforates the Constrictor pharyngis superior and ramifies in the palatine tonsil and root of the tongue.

The **glandular branches** are three or four large vessels, which supply the submaxillary gland, the neighbouring muscles, the submaxillary lymph-glands, and the skin.

The **submental artery**, the largest of the cervical branches, springs from the external maxillary artery just as that vessel quits the submaxillary gland: it runs forwards upon the Mylohyoideus, below the body of the mandible, and beneath the Digastricus. It supplies the surrounding muscles, and anastomoses with the sublingual artery and with the mylohyoid branch of the inferior alveolar; at the chin it turns upwards over the inferior border of the mandible and divides into a superficial and a deep branch. The superficial branch passes between the integument and Quadratus labii inferioris, and anastomoses with the inferior labial artery; the deep branch runs between the muscle and the bone, supplies the lip, and anastomoses with the inferior labial and mental arteries.

The **inferior labial artery** (inferior coronary artery) arises near the angle of the mouth; it passes upwards and forwards beneath the Triangularis, and, penetrating the Orbicularis oris, runs in a tortuous course along the edge of the lower lip between this muscle and the mucous membrane. It supplies the glands, mucous membrane and muscles of the lower lip; and anastomoses with the artery of the opposite side, and with the mental branch of the inferior alveolar artery.

The **superior labial artery** (superior coronary artery) is larger and more tortuous than the inferior. It follows a similar course along the edge of the upper lip, lying between the mucous membrane and the Orbicularis oris, and anastomoses with the artery of the opposite side. It supplies the upper lip, and gives off a *septal branch* which ramifies on the nasal septum as far as the point of the nose, and an *alar branch* which supplies the ala of the nose.

The **lateral nasal branch** is derived from the external maxillary, as that vessel ascends along the side of the nose. It supplies the ala and dorsum of the nose, anastomosing with its fellow, with the septal and alar branches, with the dorsal nasal branch of the ophthalmic, and with the infraorbital branch of the internal maxillary.


The **angular artery** is the terminal part of the external maxillary; it ascends to the medial angle of the orbit, imbedded in the fibres of the angular head of the Quadratus labii superioris, and accompanied by the angular vein. On the cheek it anastomoses with the infraorbital, and, after supplying the lacrimal sac and Orbicularis oculi, ends by anastomosing with the dorsal nasal branch of the ophthalmic artery.

The anastomoses of the external maxillary artery are very numerous, not only with the branches of the vessel of the opposite side, but, *in the neck*, with the sublingual branch of the lingual, with the ascending pharyngeal, and with the palatine branch of the internal maxillary; *on the face*, with the mental branch of the inferior alveolar, the transverse facial branch of the superficial temporal, the infraorbital branch of the internal maxillary, and the dorsal nasal branch of the ophthalmic.

Peculiarities.—The external maxillary artery not infrequently arises in common with the lingual. It varies in its size and in the extent to which it supplies the face; it occasionally ends as the submental, and not infrequently extends only as high as the angle of the mouth or nose. The deficiency is then compensated for by enlargement of one of the neighbouring arteries.

Applied Anatomy.—The passage of the external maxillary artery over the body of the mandible would appear to afford a favourable position for the application of pressure.

in cases of hæmorrhage from the lips; but such application is useless, except for a very short time, on account of the free communication of the artery with its fellow, and with numerous branches from different sources. In a wound involving the lip, it is better to seize the part between the fingers, and evert it, when the bleeding vessel may be at once secured with pressure-forceps. In order to prevent hæmorrhage during the removal of growths from the lip, the latter should be compressed on either side between the fingers and thumb, or by a pair of specially devised clamp-forceps, while the surgeon excises the diseased part. In order to stop hæmorrhage when the lip has been divided in an operation, it is necessary, when closing the wound, to pass the sutures through the cut edges, almost as deep as its mucous surface; by these means, not only are the cut surfaces more neatly and securely adapted to each other, but the possibility of hæmorrhage is prevented by including the divided artery in the suture. If, on the contrary, the suture be passed through merely the cutaneous portion of the wound, hæmorrhage occurs into the cavity of the mouth. The student should observe that the angular artery ascends on the nasal side of the lacrimal sac; in operating for fistula lacrimonalis, the sac should always be opened on its lateral side, in order to avoid this vessel.

 The occipital artery (fig. 617) arises from the posterior part of the external carotid, opposite the external maxillary artery, and near the lower margin of the posterior belly of the Digastricus; it ends in the posterior part of the scalp.

Relations.—At its origin, it is covered by the posterior belly of the Digastricus and the Stylohyoideus, and the hypoglossal nerve winds round it from behind forwards: higher up, it crosses the internal carotid artery, the internal jugular vein, and the vagus and accessory nerves. It next ascends along the lower border of the posterior belly of the Digastric to the interval between the transverse process of the atlas and the mastoid process of the temporal bone, and passes horizontally backwards, grooving the surface of the latter bone, being covered by the Sternocleidomastoideus, Splenius capitis, Longissimus capitis, and Digastricus, and resting upon the Rectus capitis lateralis, Obliquus superior, and Semispinalis capitis. It then runs vertically upwards, pierces the fascia connecting the cranial attachment of the Trapezius with the Sternocleidomastoideus, and ascends in a tortuous course in the superficial fascia of the scalp, where it divides into numerous branches. Its terminal portion is accompanied by the greater occipital nerve.

The branches of the occipital artery are:

Sternocleidomastoid.	Auricular.	Meningeal.
Mastoid.	Muscular (ramus descendens).	Occipital.

The **sternocleidomastoid branch** generally arises from the beginning of the occipital artery, but sometimes springs directly from the external carotid. It passes downwards and backwards over the hypoglossal nerve, and enters the substance of the Sternocleidomastoideus, in company with the accessory nerve; it anastomoses with the sternocleidomastoid branch of the superior thyroid artery.

The **mastoid branch**, small in size and sometimes absent, enters the cranial cavity through the mastoid foramen; it gives branches to the mastoid cells and dura mater and anastomoses with the middle meningeal artery.

The **auricular branch** supplies the back of the concha and anastomoses with the posterior auricular artery.

Muscular branches are supplied to the Digastricus, Stylohyoideus, Splenius, and Longissimus capitis. A large vessel, named the *ramus descendens* (arteria princeps cervicis) (fig. 621), runs downwards on the back of the neck, and divides into a superficial and a deep portion. The superficial portion passes beneath the Splenius, giving off branches which pierce that muscle to supply the Trapezius and anastomose with the ascending branch of the transverse cervical artery; the deep portion descends between the Semispinales capitis and colli, and anastomoses with the vertebral and with the arteria profunda cervicalis, a branch of the costocervical trunk. The anastomosis between these vessels assists in establishing the collateral circulation after ligature of the common carotid or subclavian artery.

The **meningeal branches** ascend with the internal jugular vein, and enter the skull through the jugular foramen and condyloid canal, to supply the dura mater in the posterior fossa.

The **occipital branches**, the terminal branches, are distributed to the scalp, and reach as high as the vertex of the skull; they are very tortuous, and lie between the skin and the Occipitalis, anastomosing with the artery of the opposite side and with the posterior auricular and temporal arteries, and supplying the Occipitalis.

the skin, and the pericranium. One of the terminal branches may give off a meningeal twig which passes through the parietal foramen.

6. The **posterior auricular artery** (fig. 617) is small and arises from the external carotid immediately above the *Digastricus* and *Stylohyoideus*. It ascends, under cover of the parotid gland, on the styloid process of the temporal bone, to the groove between the cartilage of the auricle and the mastoid process, where it divides into auricular and occipital branches.

In addition to supplying small branches to the *Digastricus*, *Stylohyoideus*, *Sternocleidomastoideus*, and parotid gland, this vessel gives off the three following branches :

Stylomastoid.

Auricular.

Occipital.

The **stylomastoid artery** enters the stylomastoid foramen and supplies the tympanic cavity, the tympanic antrum, the mastoid cells, and the semicircular canals. In the young subject a branch from this vessel forms, with the anterior tympanic artery from the internal maxillary, a vascular circle which surrounds and supplies small vessels to the tympanic membrane. It anastomoses with the superficial petrosal branch of the middle meningeal artery by a twig which enters the hiatus canalis facialis.

The **auricular branch** ascends beneath the *Auricularis posterior*, and ramifies on the back of the auricle ; some of its branches curve round the margin of the auricle and others pierce it, to supply its lateral surface. It anastomoses with the parietal and anterior auricular branches of the superficial temporal artery.

The **occipital branch** passes backwards over the *Sternocleidomastoideus* to the *Occipitalis* muscle and the scalp above and behind the ear ; it anastomoses with the occipital artery.

7. The **superficial temporal artery** (fig. 617), the smaller terminal branch of the external carotid, begins in the substance of the parotid gland, behind the neck of the mandible, and crosses over the posterior root of the zygomatic process of the temporal bone ; about 5 cm. above this process it divides into a frontal and a parietal branch.

Relations.—As it crosses the zygomatic process, it is covered by the *Auricularis anterior* muscle, and by a dense fascia ; it is crossed by the temporal and zygomatic branches of the facial nerve and is accompanied by the auriculotemporal nerve, which lies immediately behind it.

It supplies some twigs to the parotid gland, the temporomandibular joint, and the *Masseter* muscle, and gives off the following branches :

Transverse facial.

Zygomatico-orbital.

Frontal.

Anterior auricular.

Middle temporal.

Parietal.

The **transverse facial artery** is given off from the superficial temporal before that vessel quits the parotid gland ; it runs forwards through the substance of the gland, passes transversely across the side of the face between the parotid duct and the lower border of the zygomatic arch and divides into numerous branches which supply the parotid gland and duct, the *Masseter*, and the integument, and anastomose with the external maxillary, masseteric, buccinator, and infraorbital arteries. This vessel rests on the *Masseter*, and is accompanied by one or two branches of the facial nerve.

The **anterior auricular branches** are distributed to the lobule and anterior portion of the auricle, and to the external meatus ; they anastomose with the posterior auricular artery.

The **zygomatico-orbital artery**, sometimes a branch of the middle temporal artery, runs along the upper border of the zygomatic arch between the two layers of the temporal fascia to the lateral angle of the orbit. It supplies the *Orbicularis oculi* and anastomoses with the lacrimal and palpebral branches of the ophthalmic artery.

The **middle temporal artery** arises immediately above the zygomatic arch, and, perforating the temporal fascia, gives branches to the *Temporalis* muscle ; it anastomoses with the deep temporal branches of the internal maxillary artery.

The **frontal branch** runs tortuously upwards and forwards towards the frontal tuberosity ; it supplies the muscles, skin, and pericranium in this region, and anastomoses with the supraorbital and frontal arteries.

The *parietal branch*, larger than the frontal, curves upwards and backwards on the side of the head, lying superficially to the temporal fascia, and anastomosing with its fellow of the opposite side, and with the posterior auricular and occipital arteries.

Applied Anatomy.—As the superficial temporal artery crosses the zygomatic process, it lies beneath the skin and fascia, and its pulsations may be readily felt during the administration of an anæsthetic, or under circumstances where the radial pulse is not available; it may be easily compressed against the bone in order to check bleeding from the temporal region of the scalp. When a flap is raised from this part of the head, for trephining, the incision should be shaped like a horseshoe, with its convexity upwards, so that the flap shall contain the superficial temporal artery, which ensures a sufficient supply of blood. The same principle is applied, as far as possible, in making incisions to raise flaps in other parts of the scalp.

8. The *internal maxillary artery* (figs. 618, 619), the larger terminal branch of the external carotid, arises behind the neck of the mandible, and is at first imbedded in the substance of the parotid gland; it passes forwards between the ramus of the mandible and the sphenomandibular ligament, and then runs, either superficial or deep to the Pterygoideus externus, to the pterygopalatine fossa. It may be divided into mandibular, pterygoid, and pterygopalatine portions.

The *first or mandibular portion* passes horizontally forwards, between the ramus of the mandible and the sphenomandibular ligament, where it lies parallel to and a little below the auriculotemporal nerve; it crosses the inferior alveolar nerve, and runs along the lower border of the Pterygoideus externus.

The *second or pterygoid portion* runs obliquely forwards and upwards under cover of the ramus of the mandible and the insertion of the Temporalis, superficially to the lower head of the Pterygoideus externus; very frequently it lies beneath this muscle between it and the branches of the mandibular nerve.

The *third or pterygopalatine portion* passes between the two heads of the Pterygoideus externus, and through the pterygomaxillary fissure into the pterygopalatine fossa, where it lies in front of the sphenopalatine ganglion.

The branches of the vessel may be divided into three groups (fig. 619), corresponding with its three portions.

BRANCHES OF THE FIRST OR MANDIBULAR PORTION

Anterior tympanic.
Deep auricular.

Middle meningeal.
Accessory meningeal.

Inferior alveolar.

The *anterior tympanic artery* ascends behind the temporomandibular joint, and enters the tympanic cavity through the petrotympanic fissure; it ramifies upon the tympanic membrane, forming a vascular circle around it with the stylo-mastoid branch of the posterior auricular; it anastomoses with the artery of the pterygoid canal and with the caroticotympanic branch from the internal carotid.

The *deep auricular artery* often arises in common with the anterior tympanic. It ascends in the substance of the parotid gland, behind the temporomandibular joint, pierces the cartilaginous or bony wall of the external acoustic meatus, and supplies its cartilaginous lining and the outer surface of the tympanic membrane; it gives a branch to the temporomandibular joint.

The *middle meningeal artery* is the largest of the meningeal arteries. It ascends between the sphenomandibular ligament and the Pterygoideus externus and between the two roots of the auriculotemporal nerve to the foramen spinosum of the sphenoidal bone, through which it enters the cranial cavity; it then runs forwards in a groove on the great wing of the sphenoidal bone, and divides into two branches, anterior and posterior. The *anterior branch*, the larger, crosses the great wing of this bone, reaches the groove, or canal, in the sphenoidal angle of the parietal bone, and then divides into branches which spread out between the dura mater and internal table of the cranium, some passing upwards as far as the vertex, and others forwards to the occipital region. The *posterior branch* curves backwards on the squamous part of the temporal bone, and, reaching the squamous border of

the parietal bone some distance in front of its mastoid angle, divides into branches which supply the posterior part of the dura mater and cranium. The branches

FIG. 618.—The internal maxillary artery.

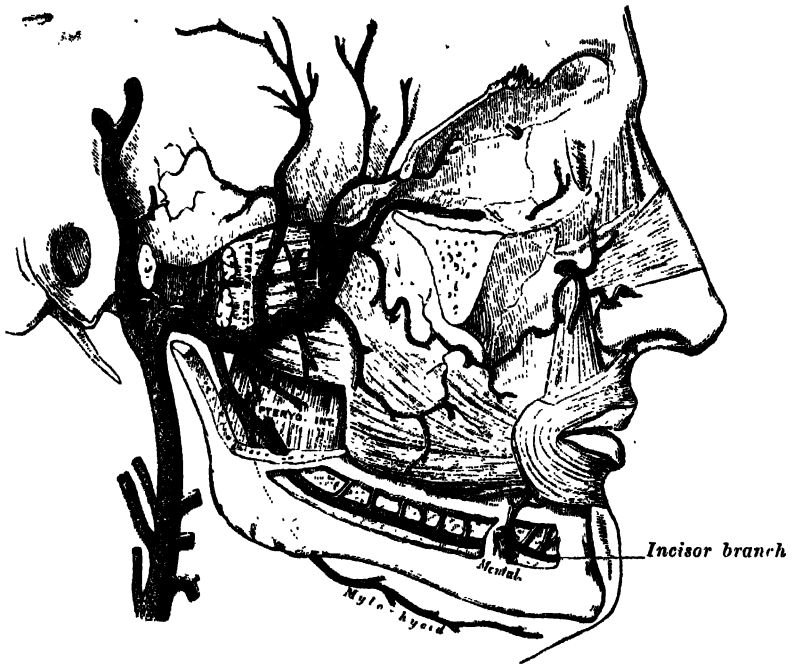
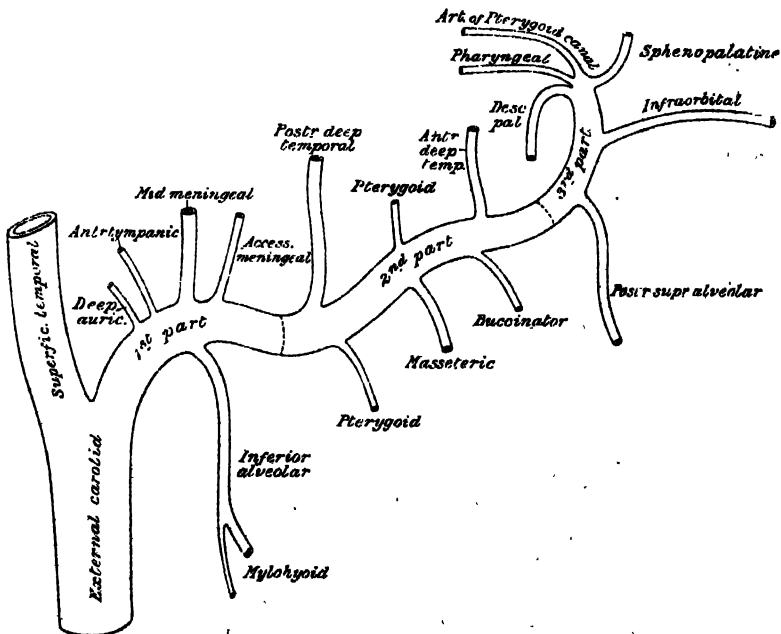


FIG. 619.—Plan of branches of internal maxillary artery.



of the middle meningeal artery anastomose with the arteries of the opposite side, and with the anterior and posterior meningeal arteries.

The middle meningeal gives off the following branches within the cranial cavity:
1. Numerous small ganglionic branches supply the semilunar ganglion and the roots of

the trigeminal nerve. 2. A *superficial petrosal branch* enters the hiatus of the facial canal, gives twigs to the facial nerve and tympanic cavity, and anastomoses with the stylomastoid branch of the posterior auricular artery. 3. A *superior tympanic artery* runs in the semicanal for the Tensor tympani, and supplies this muscle and the lining membrane of the canal. 4. *Orbital branches* pass through the superior orbital fissure and anastomose with the lacrimal or other branches of the ophthalmic artery. 5. *Temporal branches* pass through foramina in the great wing of the sphenoid, and anastomose in the temporal fossa with the deep temporal arteries.

Applied Anatomy.—The middle meningeal artery is of considerable surgical importance, as it may be torn in fractures of the temporal region of the skull, or, indeed, by injuries causing separation of the dura mater from the bone without fracture. The injury may be followed by considerable hæmorrhage between the bone and dura mater, which produces symptoms of compression of the brain, and requires trephining for its relief. As the compression implicates the motor region of the cortex, paralysis on the opposite side of the body forms the prominent symptom of the lesion. The anterior branch of this artery crosses the sphenoidal angle of the parietal bone at a point 4 cm. behind the zygomatic process of the frontal bone, and 4·5 cm. above the zygomatic arch. From this point it passes upwards and slightly backwards to the sagittal suture, lying about 1·25 to 2 cm. behind the coronal suture. The posterior branch runs backwards over the squama of the temporal bone. In order to expose the anterior branch of the artery, a point is taken 4 cm. above the zygomatic arch and the same distance behind the zygomatic process of the frontal bone. Here the pin of the trephine is to be applied. A horseshoe-shaped flap, measuring 8 cm. in length and transversely, and consisting of all the structures of the scalp down to and including the pericranium, is first made, with its base just above the zygomatic arch. This flap is reflected and a 2·5 cm. trephine applied. After the circle of bone has been removed, the blood-clot is exposed, and gently got rid of, and if possible the bleeding point must be found and controlled.

The *accessory meningeal branch* may arise from the internal maxillary or the middle meningeal artery. It enters the cranial cavity through the foramen ovale, and supplies the semilunar ganglion and dura mater.

The *inferior alveolar artery* (inferior dental artery) descends with the inferior alveolar nerve to the mandibular foramen on the medial surface of the ramus of the mandible. It runs in the mandibular canal, accompanied by the inferior alveolar nerve, and, opposite the first premolar tooth, divides into two branches, incisor and mental. The *incisor* branch is continued forwards beneath the incisor teeth as far as the middle line, where it anastomoses with the artery of the opposite side; the inferior alveolar artery and its incisor branch give off a few twigs to the mandible, and a series of branches which correspond in number to the roots of the teeth; these enter the minute apertures at the extremities of the roots, and supply the pulp of the teeth. The *mental* branch escapes at the mental foramen, supplies the chin, and anastomoses with the submental and inferior labial arteries. Near its origin the inferior alveolar artery gives off a *lingual* branch which descends with the lingual nerve and supplies the mucous membrane of the mouth. Before the inferior alveolar artery enters the mandibular foramen, it gives off a *mylohyoid* branch which runs in the mylohyoid groove with the mylohyoid nerve, and ramifies on the under surface of the Mylohyoideus.

BRANCHES OF THE SECOND OR PTERYGOID PORTION

Deep temporal.
Pterygoid.

Masseteric.
Buccinator.

The *deep temporal branches*, an anterior and a posterior, ascend between the Temporalis and the pericranium; they supply the muscle, and anastomose with the middle temporal artery; the anterior communicates with the lacrimal artery by means of small branches which perforate the zygomatic bone and great wing of the sphenoidal bone.

The *pterygoid branches*, irregular in their number and origin, supply the Pterygoidei.

The *masseteric artery* is small and passes with the masseteric nerve through the mandibular notch behind the tendon of the Temporalis muscle to the deep surface of the Masseter. It supplies the Masseter muscle, and anastomoses with the masseteric branches of the external maxillary and with the transverse facial artery.

The **buccinator artery** is small and runs obliquely forwards with the buccinator nerve, between the Pterygoideus internus and the insertion of the Temporalis, to the outer surface of the Buccinator muscle, to which it is distributed, anastomosing with branches of the external maxillary and with the infraorbital.

BRANCHES OF THE THIRD OR PTERYGOPALATINE PORTION

Posterior superior alveolar.
Infraorbital.
Descending palatine.

Artery of the pterygoid canal.
Pharyngeal.
Sphenopalatine.

The **posterior superior alveolar artery** (posterior dental artery) is given off from the internal maxillary as that vessel enters the pterygopalatine fossa; it frequently arises in conjunction with the infraorbital artery. Descending upon the infratemporal surface of the maxilla, it divides into numerous branches, some of which enter the alveolar canals to supply the molar and premolar teeth and the lining of the maxillary sinus, while others are continued forwards on the alveolar process to supply the gums.)

The **infraorbital artery** often arises in conjunction with the posterior superior alveolar. It runs along the infraorbital groove and canal with the infraorbital nerve, and emerges with the nerve on the face through the infraorbital foramen, beneath the infraorbital head of the Quadratus labii superioris. While in the canal, it gives off (a) orbital branches which assist in supplying the Rectus inferior and Obliquus inferior and the lacrimal sac, and (b) anterior superior alveolar branches which descend through the anterior alveolar canals to supply the upper incisor and canine teeth and the mucous membrane of the maxillary sinus. On the face, some branches ascend to the medial angle of the orbit and the lacrimal sac, anastomosing with the angular branch of the external maxillary artery; others run towards the nose, anastomosing with the dorsal nasal branch of the ophthalmic; and others descend between the Quadratus labii superioris and the Caninus, and anastomose with the external maxillary, transverse facial, and buccinator arteries.

The remaining branches of the internal maxillary artery arise from that portion of the artery which is contained in the pterygopalatine fossa.

The **descending palatine artery** descends through the pterygopalatine canal with the anterior palatine branch of the sphenopalatine ganglion, and gives off two or three smaller palatine arteries which are transmitted through the lesser palatine canals to supply the soft palate and palatine tonsil, and to anastomose with the ascending palatine artery. The continuation of the vessel is termed the **greater palatine artery**; it emerges on the oral surface of the palate through the greater palatine foramen, runs forwards in a groove near the alveolar border of the hard palate to the incisive canal; its terminal branch passes upwards through this canal, and anastomoses with a branch of the sphenopalatine artery. Branches are distributed to the gums, the palatine glands, and the mucous membrane of the roof of the mouth.

Applied Anatomy.—The position of the descending palatine artery on the hard palate should be borne in mind in performing an operation for the closure of a cleft in the hard palate, as it is in danger of being wounded, and may give rise to formidable hæmorrhage; it has even been found necessary to plug the pterygopalatine canal in order to arrest the bleeding.

The **artery of the pterygoid canal** (Vidian artery), frequently a branch of the descending palatine artery, passes backwards along the pterygoid canal with the corresponding nerve. It is distributed to the upper part of the pharynx and to the auditory tube, and sends into the tympanic cavity a small branch which anastomoses with the other tympanic arteries.

The **pharyngeal branch** is very small; it runs backwards through the pharyngeal canal with the pharyngeal nerve, and is distributed to the roof of the nose and pharynx, to the sphenoidal sinus, and the auditory tube.

The artery of the pterygoid canal and the pharyngeal branch lie on the lateral and medial aspects respectively of the sphenopalatine ganglion, while the trunk of the internal maxillary artery is in front of it.

The **sphenopalatine artery** is really the terminal part of the internal maxillary; it passes through the sphenopalatine foramen into the cavity of the nasal fossa.

posterior part of the superior meatus. Here it gives off its *posterior lateral nasal* branches which ramify over the conchæ and meatuses, anastomose with the ethmoidal arteries and the nasal branches of the descending palatine, and assist in supplying the frontal, maxillary, ethmoidal, and sphenoidal sinuses. Crossing the under surface of the sphenoidal bone, the sphenopalatine artery ends on the nasal septum as the *posterior septal* branches, which anastomose with the ethmoidal arteries and the septal branch of the superior labial; one branch descends in a groove on the vomer to the incisive canal and anastomoses with the terminal ascending branch of the greater palatine artery.

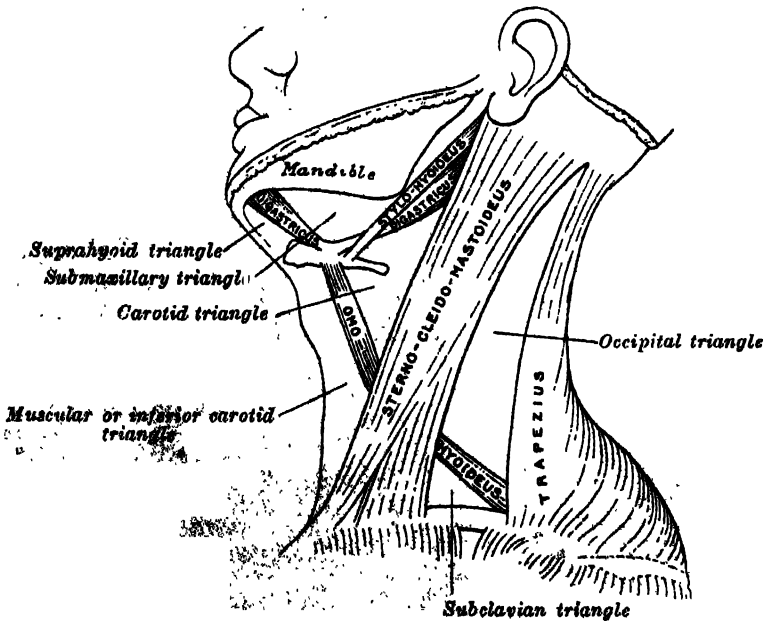
THE TRIANGLES OF THE NECK (fig. 620)

The side of the neck presents a somewhat quadrilateral outline, limited, above, by the lower border of the body of the mandible, and a line drawn from the angle of the mandible to the mastoid process; below, by the upper border of the clavicle; in front, by the middle line of the neck; behind, by the anterior margin of the Trapezius. This space is subdivided by the Sternocleidomastoideus, which passes obliquely across the neck, from the sternum and clavicle below, to the mastoid process and occipital bone above. The area in front of this muscle is called the *anterior triangle* of the neck; that behind it, the *posterior triangle*.

ANTERIOR TRIANGLE OF THE NECK

The anterior triangle of the neck is bounded anteriorly by the middle line of the neck, posteriorly, by the anterior margin of the Sternocleidomastoideus;

FIG. 620.—The triangles of the neck.



its base, directed upwards, is formed by the lower border of the body of the mandible, and a line from the angle of the mandible to the mastoid process; its apex is below, at the sternum. This space is subdivided into four smaller triangles which are named the muscular, carotid, submaxillary, and

The muscular, or inferior carotid, triangle is bounded, in front, by the median line of the neck from the hyoid bone to the sternum; behind, by the anterior margin of the Sternocleidomastoideus; above, by the superior belly of the Omohyoideus. It is covered by the skin, superficial fascia, Platysma and deep fascia, ramifying in which are some of the branches of the cutaneous cervical and supraclavicular nerves. Beneath these superficial structures are the Sternohyoideus and Sternothyroideus, which, together with the anterior margin of the Sternocleidomastoideus, conceal the lower part of the carotid sheath and its contents. In front of the sheath are a few descending filaments from the ansa hypoglossi; behind the sheath are the inferior thyroid artery, the recurrent nerve, and the sympathetic trunk; and on its medial side, the oesophagus, the trachea, the thyroid gland, and the lower part of the larynx.

The carotid triangle is limited, behind, by the Sternocleidomastoideus; below, by the superior belly of the Omohyoideus; and above, by the Stylohyoideus and the posterior belly of the Digastricus. It is covered by the skin, superficial fascia, Platysma, and deep fascia, ramifying in which are branches of the facial and the cutaneous cervical nerves. Its floor is formed by parts of the Thyrohyoideus, Hyoglossus, and the Constrictores pharyngis medius and inferior. When this space is dissected it is seen to contain the upper part of the common carotid artery, which bifurcates opposite the superior border of the thyroid cartilage into the external and internal carotid arteries. These vessels are somewhat concealed from view by the anterior margin of the Sternocleidomastoideus, which overlies them. The external and internal carotid arteries lie side by side, the external being the more anterior. The following branches of the external carotid artery are also met with: the superior thyroid, running forwards and downwards; the lingual, directly forwards; the external maxillary, forwards and upwards; the occipital, backwards; and the ascending pharyngeal, directly upwards on the medial side of the internal carotid. The veins met with are the internal jugular, which lies on the lateral side of the common and external carotid arteries; and veins corresponding to the above-mentioned branches of the external carotid artery—viz. the superior thyroid, the lingual, common facial, ascending pharyngeal, and sometimes the occipital—all of which end in the internal jugular vein. The nerves are the following. In front of the sheath of the common carotid artery is the ramus descendens hypoglossi. The hypoglossal nerve crosses both the internal and external carotid arteries, curving round the origin of the occipital artery. Within the sheath, between the common carotid artery and the internal jugular vein, and behind both, is the vagus nerve; behind the sheath, the sympathetic trunk. The accessory nerve descends for a short distance on the lateral side of the vessels before it pierces the Sternocleidomastoideus; and on the medial side of the external carotid artery, just below the hyoid bone, may be seen the internal branch of the superior laryngeal nerve; and, still more inferiorly, the external branch of the same nerve. The upper portion of the larynx and lower portion of the pharynx are also found in the anterior part of this triangle.

The submaxillary, or digastric, triangle is bounded, above, by the lower border of the body of the mandible, and a line drawn from its angle to the mastoid process; below, by the posterior belly of the Digastricus and the Stylohyoideus; in front, by the anterior belly of the Digastricus. It is covered by the skin, superficial fascia, Platysma, and deep fascia, ramifying in which are branches of the facial and cutaneous cervical nerves. Its floor is formed by the Mylohyoideus, Hyoglossus, and Constrictor pharyngis superior. It is divided into an anterior and a posterior part by the stylomandibular ligament. The anterior part contains the submaxillary gland, superficial to which is the anterior facial vein, while imbedded in a groove on the posterior border of the gland is the external maxillary artery; beneath the gland, on the surface of the Mylohyoideus, are the submental artery and the mylohyoid artery and nerve. The posterior part of this triangle contains the external carotid artery, which ascends deeply in the substance of the parotid gland; in this triangle the external carotid artery is in front of, and superficial to, the internal carotid artery, and is crossed by the facial nerve; it gives off in its course the posterior auricular, superficial temporal, and internal maxillary

branches; more deeply are the internal carotid artery, the internal jugular vein, and the vagus nerve, which are separated from the external carotid artery by the Styloglossus, the Stylopharyngeus, and the glossopharyngeal nerve.

The **suprahyoid-triangle** is limited, behind, by the anterior belly of the Digastricus, in front, by the middle line of the neck from the mandible to the hyoid bone, and below, by the body of the hyoid bone; its floor is formed by the Mylohyoideus. It contains one or two lymph-glands and some small veins; the latter unite to form the anterior jugular vein.

POSTERIOR TRIANGLE OF THE NECK

The **posterior triangle** of the neck is bounded, in front, by the Sternocleidomastoideus; behind, by the anterior margin of the Trapezius; its base is formed by the middle third of the clavicle; its apex is at the occipital bone between the attachments of the Sternocleidomastoideus and the Trapezius. The triangle is crossed, about 2.5 cm. above the clavicle, by the inferior belly of the Omohyoideus, which divides the triangle into an occipital and a subclavian triangle.

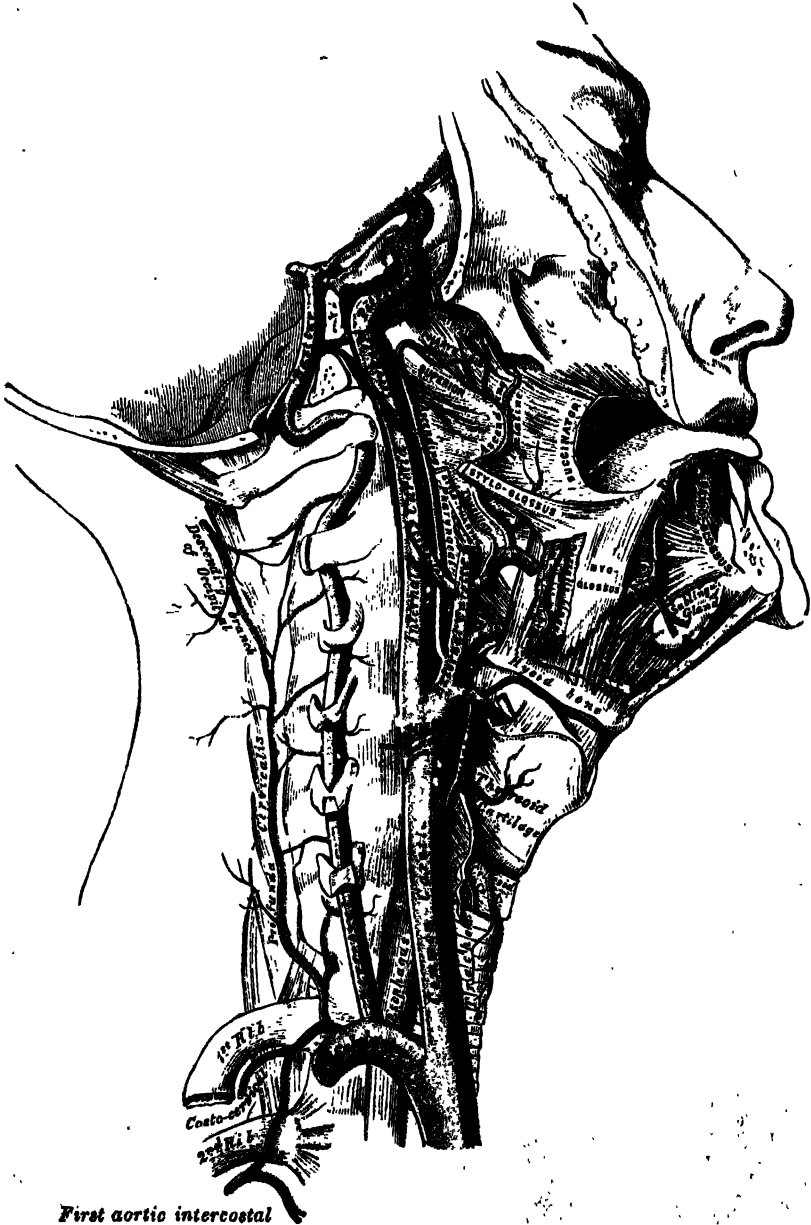
The **occipital triangle**, the upper and larger division of the posterior triangle, is bounded in front by the Sternocleidomastoideus; behind, by the Trapezius; below, by the Omohyoideus. Its floor is formed from above downwards by the Splenius capitis, Levator scapulæ, and the Scaleni medius and posterior. It is covered by the skin, the superficial and deep fasciæ, and by the Platysma below. The accessory nerve pierces the Sternocleidomastoideus and is directed obliquely across the space to the under surface of the Trapezius; below, the supraclavicular nerves and the transverse cervical vessels and the upper part of the brachial plexus cross the space. A chain of lymph-glands is also found running along the posterior border of the Sternocleidomastoideus, from the mastoid process to the root of the neck.

The **subclavian triangle**, the lower and smaller division of the posterior triangle, is bounded, above, by the inferior belly of the Omohyoideus; below, by the clavicle; its base is formed by the lower part of the posterior border of the Sternocleidomastoideus. Its floor consists of the first rib and the first digitation of the Serratus anterior. The size of this triangle varies with the extent of attachment of the clavicular portions of the Sternocleidomastoideus and Trapezius, and also with the level at which the inferior belly of the Omohyoideus crosses the neck; this level is lowered when the arm is raised, and raised when the arm is depressed. The triangle is covered by the skin, the superficial and deep fasciæ, and the Platysma below. It is crossed by the supraclavicular nerves. Just above the level of the clavicle, the third portion of the subclavian artery curves lateralwards and downwards from the lateral margin of the Scalenus anterior, across the first rib, to the axilla. The subclavian vein lies behind the clavicle, and is not usually seen in this space; but in some cases it rises as high as the artery, and has even been seen to accompany that vessel behind the Scalenus anterior. The brachial plexus of nerves lies partly above and partly behind the artery, and in close contact with it. Passing transversely behind the clavicle are the transverse scapular vessels; and running in the same direction, but at a slightly higher level are the transverse cervical artery and vein. The external jugular vein descends behind the posterior border of the Sternocleidomastoideus, to terminate in the subclavian vein; it receives the transverse cervical and transverse scapular veins, which form a plexus in front of the third part of the subclavian artery, and occasionally it is joined by a small vein which crosses the clavicle from the cephalic vein. The small nerve to the Subclavius also crosses this triangle about its middle, and some lymph-glands are contained within the space.

INTERNAL CAROTID ARTERY

The internal carotid artery (fig. 621) supplies the greater part of the cerebral hemisphere, the eye and its appendages, and sends branches to the forehead and nose. It begins at the bifurcation of the common carotid artery,

FIG. 621.—The internal carotid and vertebral arteries. Right side.



ascends to the base of the skull, and enters the cranial cavity through the carotid canal of the temporal bone. It then runs forward through the cavernous sinus, lying in the carotid sulcus on the side of the body of the sphenoidal bone, and ends below the anterior perforated substance of the brain by dividing into the anterior and the middle cerebral arteries.

The internal carotid artery may be divided into four portions: cervical, petrous, cavernous, and cerebral.

Cervical Portion.—This portion of the internal carotid artery begins at the bifurcation of the common carotid, opposite the upper border of the thyroid cartilage and ascends in front of the transverse processes of the upper three cervical vertebrae to the lower end of the carotid canal in the petrous portion of the temporal bone. It is comparatively superficial at its commencement, where it is contained in the carotid triangle, and lies behind and lateral to the external carotid, overlapped by the Sternocleidomastoideus, and covered by the deep fascia, Platysma, and skin: it then passes beneath the parotid gland, being crossed by the hypoglossal nerve, the Digastricus and Stylohyoideus, and the occipital and posterior auricular arteries. Higher up, it is separated from the external carotid by the Styloglossus and Stylopharyngeus, the tip of the styloid process and the stylohyoid ligament, the glossopharyngeal nerve and the pharyngeal branch of the vagus. It is in relation behind, with the Longus capitis, the superior cervical ganglion of the sympathetic trunk, and the superior laryngeal nerve; laterally, with the internal jugular vein and vagus nerve, the nerve lying on a plane posterior to the artery; medially, with the internal maxillary, superior laryngeal nerve, and ascending pharyngeal artery. At the base of the skull the glossopharyngeal, vagus, accessory, and hypoglossal nerves lie between the artery and the internal jugular vein.

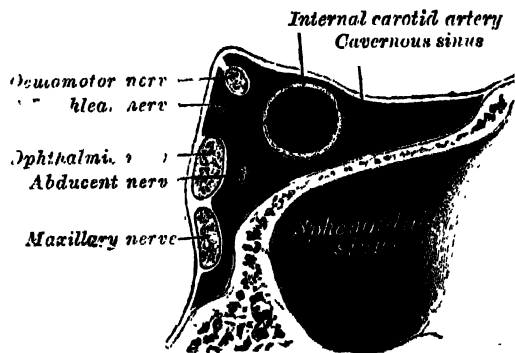
Petrous Portion.—When the internal carotid artery enters the canal in the petrous portion of the temporal bone, it first ascends a short distance, then curves forward and medialwards, and again ascends as it leaves the canal to enter the cranial cavity between the lingula and petrosal process of the sphenoidal bone. The artery lies at first in front of the cochlea and tympanic cavity; from the latter cavity it is separated by a thin, bony lamella, which is cribriform in the young subject and often partially absorbed in old age. Farther forwards it is separated from the nodular ganglion by a thin plate of bone, which forms the floor of the fossa for the ganglion and the roof of the horizontal portion of the carotid canal. Frequently this bony plate is more or less deficient, and then the ganglion is separated from the artery by fibrous membrane. The artery is surrounded by a number of small veins and the carotid plexus of nerves which is derived from the ascending branch of the superior cervical ganglion of the sympathetic trunk.

Cavernous Portion.—In this part of its course, the artery is situated between the layers of the dura mater forming the cavernous sinus (fig. 622), but covered by the lining membrane of the sinus. It at first ascends towards the posterior clinoid process, then passes forwards on the side of the body of the sphenoidal bone, and again curves upwards on the medial side of the anterior clinoid process, and perforates the dura mater, forming a root of the sinus; occasionally the anterior and middle clinoid processes form a bony ring round the artery. The cavernous portion of the artery is surrounded by the cavernous plexus of the sympathetic, and lateral to it are the oculomotor, trochlear, ophthalmic and abducent nerves (fig. 622).

Cerebral Portion.—After perforating the dura mater on the medial side of the anterior clinoid process, the internal carotid passes between the optic and oculomotor nerves to the anterior perforated substance at the medial extremity of the lateral cerebral fissure, where it gives off its terminal or cerebral branches.

Peculiarities.—The length of the internal carotid varies with the length of the neck, and with the point of bifurcation of the common carotid. It arises occasionally from the arch of the aorta, and then has been found medially to the external carotid, as far upwards as the larynx, where it crossed and this vessel to reach its usual position. The course of the artery, instead of being straight, may be very tortuous. A few instances are recorded in which this vessel was absent; in one of these the common carotid passed up the neck, and gave off the branches normally arising from the external carotid; the

FIG. 622 Oblique section through the right cavernous sinus.



cranial portion of the internal carotid was replaced by two branches of the internal maxillary, which entered the skull through the foramen rotundum and foramen ovale, and joined to form a single vessel.

Applied Anatomy.—The cervical part of the internal carotid is very rarely wounded. It is, however, sometimes injured by a stab or gunshot-wound in the neck, or even occasionally by a stab from within the mouth. Although the internal carotid lies about 2 cm. behind and lateral to the tonsil, instances have occurred in which the artery has been wounded during the operation of excision of the tonsil, and fatal hæmorrhage has supervened. The incision for ligature of the cervical portion of the internal carotid should be made along the anterior border of the Sternocleidomastoideus, from the angle of the mandible to the upper border of the thyroid cartilage. The superficial structures being divided, and the Sternocleidomastoideus defined and drawn backwards, the areolar tissue must be carefully separated and the posterior belly of the Digastricus and the hypoglossal nerve sought as guides to the vessel. The external carotid should be drawn medialwards and the Digastricus upwards, and the aneurysm needle passed from the lateral to the medial side of the vessel.

Obstruction of the internal carotid by embolism or thrombosis may give rise to symptoms of cerebral anæmia and softening if the collateral circulation is ill-developed. The patient suffers from giddiness, with failure of the mental powers; and convulsions, coma, or hemiplegia on the opposite side of the body, may be observed.

Branches.—No branches arise from the cervical portion of the internal carotid artery. Those from the other portions are :

From the petrous portion

1. Caroticotympanic.
2. Pterygoid.
3. Cavernous.
4. Hypophysial.

From the cavernous portion

5. Semilunar.
6. Anterior meningeal.
7. Ophthalmic.
8. Anterior cerebral.

From the cerebral portion

9. Middle cerebral.
10. Posterior communicating.
11. Chorioidal.

1. The **caroticotympanic branch** is very small; it enters the tympanic cavity through a foramen in the wall of the carotid canal, and anastomoses with the anterior tympanic branch of the internal maxillary, and with the stylomastoid artery.

2. A small, inconstant **pterygoid branch** passes into the pterygoid canal and anastomoses with a branch of the descending palatine artery.

3. The **cavernous branches** are numerous small vessels which supply the hypophysis, the semilunar ganglion, and the walls of the cavernous and inferior petrosal sinuses. Some of them anastomose with branches of the middle meningeal artery.

4. The **hypophysial branches** are one or two minute vessels which supply the hypophysis.

5. The **semilunar branches** are small vessels supplying the semilunar ganglion.

6. The **anterior meningeal branch** is a minute branch which passes over the small wing of the sphenoid to supply the dura mater of the anterior cranial fossa; it anastomoses with the meningeal branch from the posterior ethmoidal artery.

7. The **ophthalmic artery** (fig. 623) arises from the internal carotid, just as that vessel is emerging from the cavernous sinus on the medial side of the anterior clinoid process; it enters the orbital cavity through the optic foramen, below and laterally to the optic nerve. In the orbital cavity it runs for a short distance laterally to the optic nerve and medially to the Rectus lateralis and ciliary ganglion. It then crosses obliquely over the nerve to reach the medial wall of the orbit, and thence passes horizontally forwards, beneath the lower border of the Obliquus superior, and divides into two terminal branches, the *frontal* and the *dorsal nasal*. As the artery crosses the optic nerve it is accompanied by the nasociliary nerve, and is separated from the frontal nerve by the Rectus superior and Levator palpebræ superioris.

The branches of the ophthalmic artery are :—

Central artery of retina.

Lacrimal.

Muscular.

Short posterior ciliary.

Long posterior ciliary.

Anterior ciliary.

Supraorbital.

Posterior ethmoidal.

Anterior ethmoidal.

Anterior meningeal.

Medial palpebral.

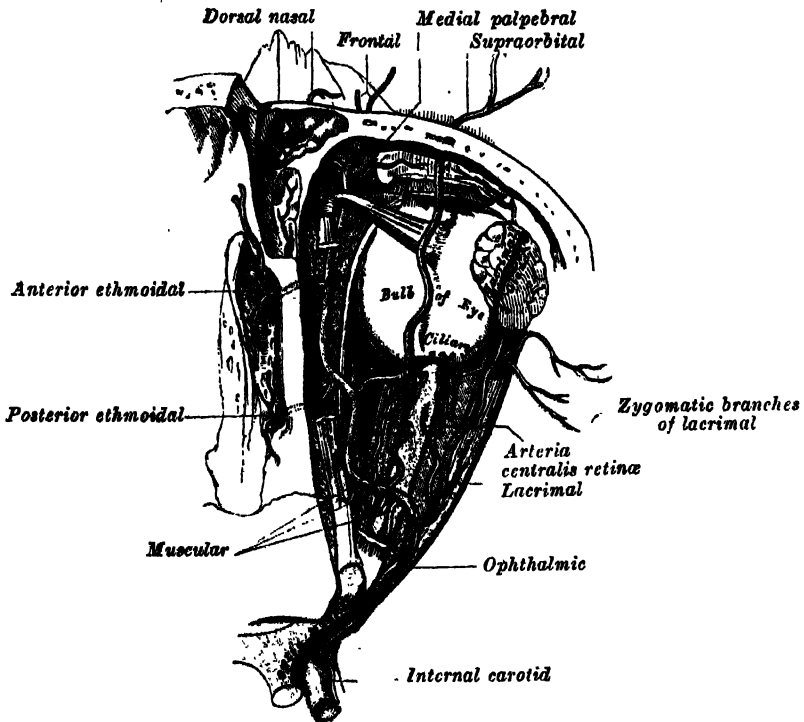
Frontal.

Dorsal nasal.

The *central artery of the retina* is the first and one of the smallest branches of the ophthalmic artery. It runs for a short distance within the dural sheath of the optic nerve, and about 1.25 cm. behind the eyeball it pierces the under surface of the nerve, and runs forward in its centre to the retina. Its mode of distribution is described with the anatomy of the eye.

The *lacrimal artery* arises close to the optic foramen, and is one of the largest branches of the ophthalmic artery: sometimes it is given off before the ophthalmic artery enters the orbit; occasionally it is derived from one of the anterior branches of the middle meningeal artery. It accompanies the lacrimal nerve along the upper border of the Rectus lateralis, and supplies the lacrimal gland. Its terminal branches, escaping from the gland, are distributed to the eyelids and conjunctiva: of those supplying the eyelids, two are of considerable size and are named the *lateral palpebral arteries*; they run medialwards in the upper and lower lids respectively and anastomose with the medial

FIG. 623.—The ophthalmic artery and its branches.



palpebral arteries. The lacrimal artery gives off one or two *zygomatic branches*, one of which passes through the zygomaticotemporal foramen to the temporal fossa, and anastomoses with the deep temporal arteries; another appears on the cheek through the zygomaticofacial foramen and anastomoses with the transverse facial. A *recurrent meningeal branch* passes backwards through the lateral part of the superior orbital fissure to the dura mater, and anastomoses with a branch of the middle meningeal artery.

The *muscular branches* frequently spring from a common trunk. They consist of a superior and an inferior group, and most of them accompany the branches of the oculomotor nerve. The superior group, often wanting, supplies the Levator palpebrae superioris, Rectus superior, and Obliquus superior. The inferior group, more constantly present, is distributed to the Recti lateralis, medialis, and inferior, and the Obliquus inferior. This group gives off most of the anterior ciliary arteries. Additional muscular branches are derived from the lacrimal and supraorbital arteries, or from the trunk of the ophthalmic artery.

The *ciliary arteries* are divisible into three groups, long and short posterior, and anterior. The *long posterior ciliary arteries*, two in number, pierce the posterior part of the sclera a short distance from the entrance of the optic nerve, and run forwards, along either side of the eyeball, between the sclera and chorioid, to the ciliary muscles, where each divides into a superior and an inferior branch; these form, together with the anterior ciliary arteries, an arterial circle, the *circulus arteriosus major*, around the circumference of the iris; from the *circulus arteriosus major* numerous converging branches run in the

substance of the iris to its pupillary margin, where they form a second arterial circle, the *circulus arteriosus minor*. The *short posterior ciliary arteries*, from six to twelve in number, arise from the ophthalmic, or its branches; they pass forwards around the optic nerve to the posterior part of the eyeball, pierce the sclera around the entrance of the nerve, and supply the choroid coat and the ciliary processes. The *anterior ciliary arteries* are derived from the muscular branches of the ophthalmic artery; they run to the front of the eyeball in company with the tendons of the Recti, form a vascular zone beneath the conjunctiva, and then pierce the sclera a short distance from the sclero-corneal junction and end in the *circulus arteriosus major*.

The *supraorbital artery* leaves the ophthalmic artery as that vessel crosses the optic nerve. It ascends on the medial borders of the Rectus superior and Levator palpebræ superioris, and meeting the supraorbital nerve accompanies it between the periosteum and Levator palpebræ superioris to the supraorbital foramen; passing through this it divides into a superficial and a deep branch, which supply the skin, muscles, and pericranium of the forehead, anastomosing with the frontal, the frontal branch of the superficial temporal, and the artery of the opposite side. In the orbit it supplies twigs to the Rectus superior and the Levator palpebræ, and sends a branch across the pulley of the Obliquus superior, to the parts at the medial palpebral commissure. At the supraorbital foramen it frequently sends a branch to the diploë.

The *posterior ethmoidal artery* runs through the posterior ethmoidal canal, supplies the posterior ethmoidal cells, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches which descend into the nasal cavity through the lamina cribrosa of the ethmoidal bone, and anastomose with branches of the sphenopalatine artery.

The *anterior ethmoidal artery* accompanies the anterior ethmoidal nerve through the anterior ethmoidal canal, supplies the anterior and middle ethmoidal cells and frontal sinus, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches; the latter descend into the nasal cavity with the anterior ethmoidal nerve and, running along the groove on the inner surface of the nasal bone, supply twigs to the lateral wall and septum of the nose, and a terminal branch which appears on the dorsum of the nose between the nasal bone and the lateral cartilage.

The *anterior meningeal artery* is a small branch which passes to the middle cranial fossa through the superior orbital fissure and anastomoses with the middle and accessory meningeal arteries.

The *medial palpebral arteries*, two in number, superior and inferior, arise from the ophthalmic, opposite the pulley of the Obliquus superior, and run lateralwards in the eyelids near their free margins, forming a superior and an inferior arch, which lie between the Orbicularis oculi and the tarsi. The superior palpebral artery anastomoses with the supraorbital artery, and, at the lateral angle of the orbit, with the zygomatico-orbital branch of the temporal artery, and with the upper of the two lateral palpebral branches of the lacrimal artery; the inferior palpebral artery anastomoses at the lateral angle of the orbit with the lower of the two lateral palpebral branches of the lacrimal and with the transverse facial artery, and at the medial part of the eyelid with a twig from the angular artery. From this last anastomosis a branch passes to the nasolacrimal duct, ramifying in its mucous membrane, as far as the inferior meatus of the nasal cavity.

The *frontal artery*, one of the terminal branches of the ophthalmic, leaves the orbit at its medial angle with the supra-trochlear nerve, and, ascending on the forehead, supplies the skin, muscles, and pericranium, anastomosing with the supraorbital artery, and with the artery of the opposite side.

The *dorsal nasal artery*, the other terminal branch of the ophthalmic, emerges from the orbit above the medial palpebral ligament, and, after giving a twig to the upper part of the lacrimal sac, divides into two branches, one of which crosses the root of the nose, and anastomoses with the angular artery; the other runs along the dorsum of the nose, supplies its outer surface, and anastomoses with the artery of the opposite side, and with the lateral nasal branch of the external maxillary artery.

8. The *anterior cerebral artery* (figs. 624, 625, 626) arises from the internal carotid artery, at the medial end of the lateral cerebral fissure. It passes forwards and medialwards across the anterior perforated substance, above the optic nerve, to the commencement of the longitudinal fissure. Here it comes into close relationship with the opposite artery and is connected with it by a short transverse trunk named the anterior communicating artery. From this point, the two anterior cerebral arteries run side by side in the longitudinal cerebral fissure, curving round the genu of the corpus callosum, and running backwards along the upper surface of this structure to its posterior extremity, where they end by anastomosing with the posterior cerebral arteries.

The *anterior communicating artery* has an average length of about 4 mm. and connects the two anterior cerebral arteries across the commencement of the longitudinal fissure; in about 7 per cent. of cases it is double. It gives off a few anteromedial ganglionic branches.

In its course the anterior cerebral artery gives off the following branches :

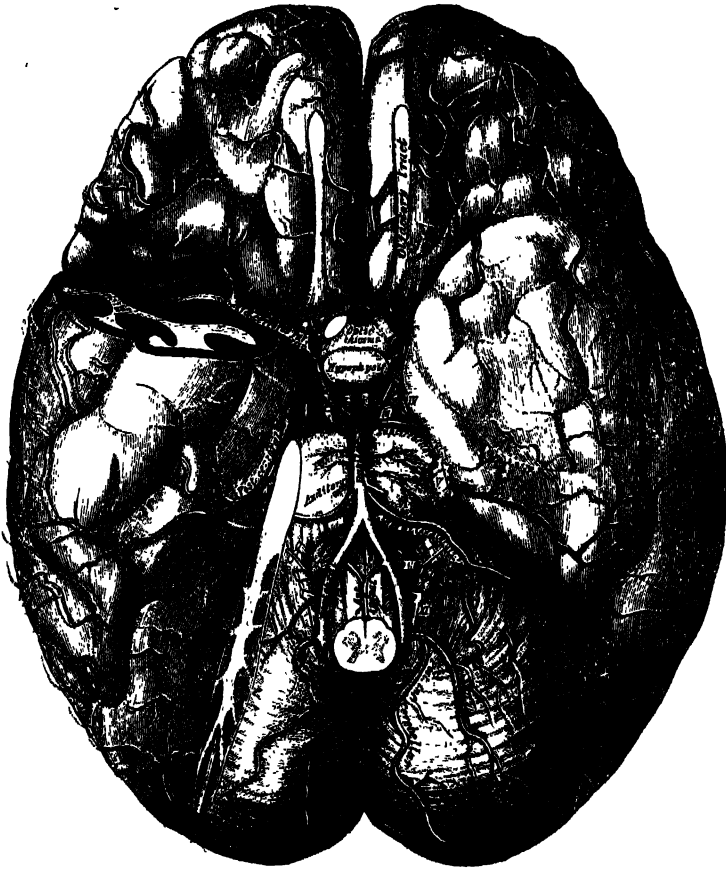
Anteromedial ganglionic.
Inferior.

Anterior.
Middle.

Posterior.

The *anteromedial ganglionic branches* are a group of small arteries which arise from the commencement of the anterior cerebral artery ; they pierce the anterior perforated substance and lamina terminalis, and supply the rostrum of the corpus callosum, the septum pellucidum, and the head of the caudate nucleus. The *inferior branches*, two or three in number, are distributed to the orbital surface of

FIG. 624.—The arteries at the base of the brain.



the frontal lobe, where they supply the olfactory lobe, gyrus rectus, and medial orbital gyrus. The *anterior branches* supply a part of the superior frontal gyrus, and send twigs over the superomedial border of the cerebral hemisphere to the superior and middle frontal gyri and upper part of the anterior central gyrus. The *middle branches* supply the corpus callosum, the cingulate gyrus, the medial surface of the superior frontal gyrus, and the upper part of the anterior central gyrus. The *posterior branches* supply the præcuneus and adjacent lateral surface of the hemisphere.

9. The *middle cerebral artery* (figs. 624, 625), the largest branch of the internal carotid artery, runs at first lateralwards in the lateral cerebral fissure and then backwards and upwards on the surface of the insula, where it divides into branches which are distributed to the insula and to the lateral surface of the cerebral hemisphere.

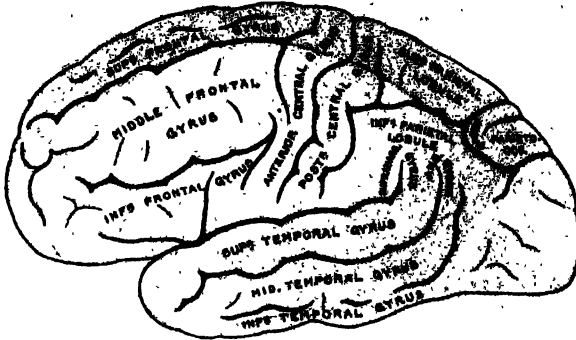
The branches of this vessel are the

Anterolateral ganglionic.
Inferior lateral frontal.
Ascending frontal.

Ascending parietal.
Parietotemporal.
Temporal.

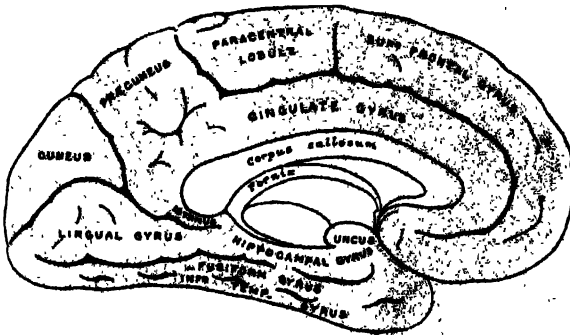
The *anterolateral ganglionic branches*, a group of small arteries which arise from the commencement of the middle cerebral artery, are arranged in two sets: one,

FIG. 625.—Lateral surface of cerebral hemisphere, showing the areas supplied by the cerebral arteries. In this and the next figure the areas supplied by the anterior cerebral artery are coloured *blue*; those by the middle cerebral artery, *pink*; and those by the posterior cerebral artery, *yellow*.



the *internal striate*, ascends through the inner segments of the lentiform nucleus, and supplies it, the caudate nucleus, and the internal capsule; the other, the *external striate*, ascends through the outer segment of the lentiform nucleus, and supplies the caudate nucleus and the thalamus. One artery of this group is larger than the rest, and of special importance, as being the artery in the brain most frequently ruptured; it has been termed by Charcot the '*artery of cerebral hæmorrhage*.' It ascends between the lentiform nucleus and the external capsule, and ends in the caudate nucleus. The *inferior lateral frontal* supplies the inferior frontal

FIG. 626.—Medial surface of cerebral hemisphere, showing the areas supplied by the cerebral arteries (see description of fig. 625).



gyrus (Broca's convolution) and the lateral part of the orbital surface of the frontal lobe. The *ascending frontal* supplies the anterior central gyrus. The *ascending parietal* is distributed to the posterior central gyrus and the lower part of the superior parietal lobule. The *parietotemporal* supplies the supramarginal and angular gyri, and the posterior parts of the superior and middle temporal gyri. The *temporal branches*, two or three in number, are distributed to the lateral surface of the temporal lobe.

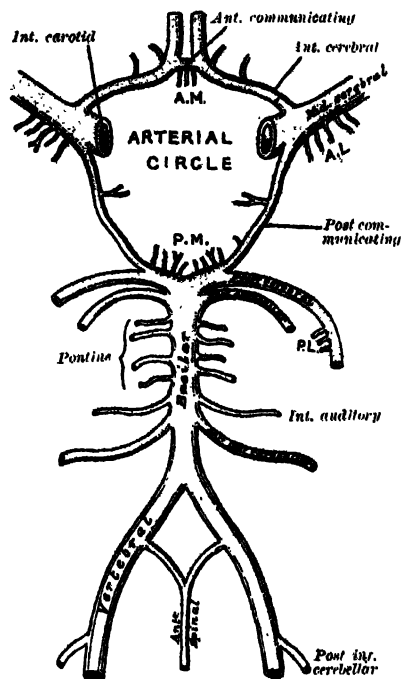
10. The *posterior communicating artery* (fig. 624) runs backwards from the internal carotid above the oculomotor nerve, and anastomoses with the posterior

cerebral, a branch of the basilar artery. It is usually a small vessel, but is occasionally so large that the posterior cerebral may be considered as arising from the internal carotid rather than from the basilar. It is frequently larger on one side than on the other. From its posterior half are given off several small *posteromedial ganglionic branches*, which, with similar vessels from the posterior cerebral artery, pierce the posterior perforated substance and supply the medial surfaces of the thalami and the walls of the third ventricle.

11. The *anterior chorioidal artery*, a small but constant branch, arises from the internal carotid, near the posterior communicating artery. Passing backwards and lateralwards between the uncus and the cerebral peduncle, it enters the inferior horn of the lateral ventricle through the chorioidal fissure and ends in the chorioid plexus. It is distributed to the hippocampus, fimbria, tela chorioides of the third ventricle, and chorioid plexus.

Arterial circle of Willis.—A considerable part of the brain is supplied by the two vertebral arteries (p. 606), and a remarkable anastomosis, named the *arterial circle of Willis*, exists between these vessels and the two internal carotid arteries. This circle is situated in the subarachnoid space at the base of the brain, and encloses the optic chiasma and the structures in the interpeduncular fossa (p. 804). It is formed as follows: in front, the two anterior cerebral arteries are joined to one another by the anterior communicating artery; behind, the basilar artery (formed by the union of the vertebral arteries) divides into the two posterior cerebral arteries, each of which is joined to the internal carotid artery of the same side by the posterior communicating artery (fig. 627).

FIG. 627.—Diagram of the arteries at the base of the brain.



A.L. Anterolateral; A.M. Anteromedial; P.L. Posterolateral; P.M. Posteromedial ganglionic branches.

THE ARTERIES OF THE BRAIN

The mode of distribution of the vessels of the brain has an important bearing upon a considerable number of the pathological lesions which may occur in this part of the nervous system.

The arteries which supply the brain give origin to two different systems of vessels. One of these is named the *ganglionic system*, and its vessels supply the thalami and corpora striata; the other is the *cortical system*, and its vessels ramify in the pia mater and supply the cortex and subjacent brain-substance. These two systems are independent of one another and do not communicate at any point of their peripheral distribution, and there is between the parts supplied by the two systems a borderland of diminished nutritive activity where, it is said, softening of the brain is especially liable to occur.

The ganglionic system.—All the vessels of this system are given off from the circle of Willis, described above, or from the vessels close to it. They form six principal groups: (i) an *anteromedial group*, derived from the anterior cerebral and anterior communicating arteries; (ii) a *posteromedial group*, from the posterior cerebral and posterior communicating arteries; (iii and iv) right and left *anterolateral groups*, from the middle cerebral arteries; and (v and vi) right and left *posterolateral groups*, from the posterior cerebral arteries after they have wound round the cerebral peduncles. The vessels of this system are larger than those of the cortical system, and are what Cohnheim designated *terminal arteries*—that is to say, vessels which from their origin to their termination neither supply nor receive any anastomotic branch, so that, through any one of the vessels only a limited area of the thalamus or corpus striatum can be injected.

The cortical system.—The vessels of this system are the terminal branches of the anterior, middle, and posterior cerebral arteries. They divide in the substance of the pia mater, give off branches which penetrate the brain-cortex perpendicularly, and are divisible into two classes, long and short. The *long*, or *medullary arteries*, pass through the grey substance and penetrate the subjacent white substance to the depth of 3 or 4 cm., without intercommunicating otherwise than by very fine capillaries, and thus constitute so many independent small systems. The *short vessels* are confined to the cortex, where they form with the long vessels a compact network in the middle zone of the grey substance, the outer and inner zones being sparingly supplied with blood. The vessels of the cortical system are not so strictly 'terminal' as those of the ganglionic system, but they approach this type very closely, so that injection of one area from the vessel of another area, though possible, is difficult, and only effected through vessels of small calibre; obstruction of one of these vessels may therefore produce softening in a limited area of the brain cortex.

ARTERIES OF THE UPPER EXTREMITY

The artery which supplies the upper extremity runs as a single trunk as far as the elbow; but is differently named, according to the regions through which it passes. From its origin to the outer border of the first rib it is termed *subclavian*; from the outer border of the first rib to the lower border of the tendon of the Teres major, it is named *axillary*; and from the lower border of the Teres major to a point opposite the neck of the radius it is termed *brachial*.

SUBCLAVIAN ARTERIES (fig. 628)

The right subclavian artery arises from the innominate artery, the left from the arch of the aorta. The vessels, therefore, in the first parts of their courses, differ in length, direction, and relation with neighbouring structures.

To facilitate the description, each subclavian artery is divided into three parts; the first extends from the origin of the vessel to the medial border of the Scalenus anterior, the second lies behind this muscle, and the third runs from the lateral margin of the muscle to the outer border of the first rib, where it becomes the axillary artery. The first portions of the two vessels require separate descriptions; their second and third parts are almost alike.

FIRST PART OF THE RIGHT SUBCLAVIAN ARTERY (figs. 621, 628)

The first part of the right subclavian artery arises from the innominate artery, behind the upper part of the right sternoclavicular articulation, and passes upwards and lateralwards to the medial margin of the Scalenus anterior. It ascends, on an average, about 2 cm. above the clavicle, but the height it reaches varies considerably in different cases.

Relations.—It is covered, *in front*, by the skin, superficial fascia, Platysma, deep fascia, the clavicular origin of the Sternocleidomastoideus, the Sternohyoideus, and Sternothyroideus. It is crossed by the internal jugular and vertebral veins, by the vagus nerve and the cardiac branches of the vagus and sympathetic; the subclavian loop of the sympathetic trunk encircles the vessel. The anterior jugular vein is directed lateralwards in front of the artery, but is separated from it by the Sternohyoideus and Sternothyroideus. *Below and behind* the artery are the pleura and the apex of the lung; *behind* is the sympathetic trunk, the Longus colli and the first thoracic vertebra. The right recurrent nerve winds round the lower and posterior part of the vessel.

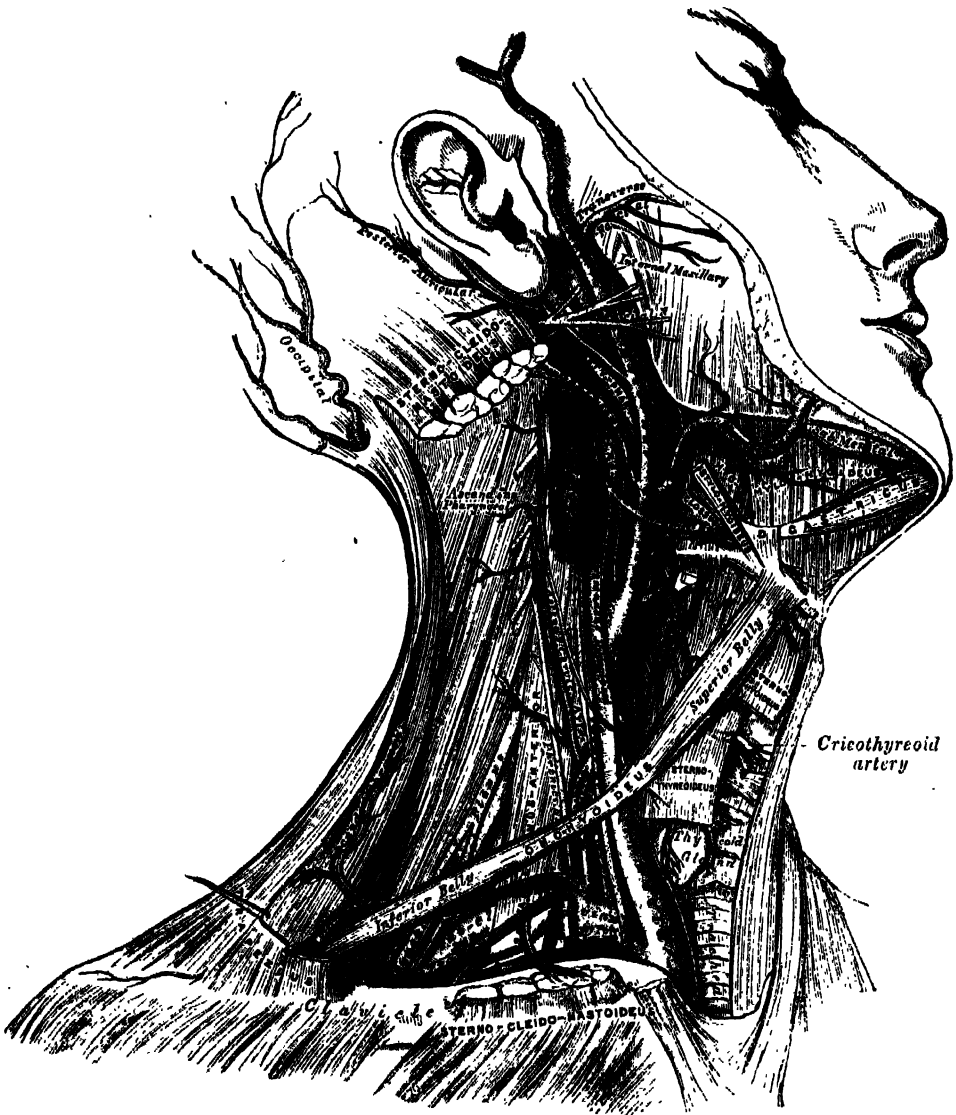
FIRST PART OF THE LEFT SUBCLAVIAN ARTERY (fig. 613)

The first part of the left subclavian artery arises from the arch of the aorta, behind the left common carotid, and at the level of the upper border of the fourth thoracic vertebra; it ascends in the superior mediastinal cavity to the root of the neck and then arches lateralwards to the medial border of the Scalenus anterior.

Relations.—It is in relation, *in front*, with the vagus, cardiac, and phrenic nerves, the left common carotid artery, the left internal jugular and vertebral veins

and the beginning of the left innominate vein, and is covered by the Sternothyroideus, Sternohyoideus, and Sternocleidomastoideus; *behind*, it is in relation with the œsophagus, thoracic duct, left recurrent nerve, inferior cervical ganglion of the sympathetic trunk, and Longus colli; higher up, however, the œsophagus and thoracic duct lie to its right side, the latter ultimately arching over the vessel to

FIG. 628.—Superficial dissection of the right side of the neck, showing the carotid and subclavian arteries.



join the angle of union between the subclavian and internal jugular veins. *Medially* to it are the œsophagus, trachea, thoracic duct, and left recurrent nerve; *laterally* to it, the left pleura and lung.

SECOND AND THIRD PARTS OF THE SUBCLAVIAN ARTERY (fig. 628)

The **second portion** of the subclavian artery lies behind the Scalenus anterior; it is very short, and forms the highest part of the arch described by the vessel.

Relations.—It is covered, *in front*, by the skin, superficial fascia, Platysma, deep cervical fascia, Sternocleidomastoideus, and Scalenus anterior. On the right side of the neck the phrenic nerve is separated from the second part of the artery by the Scalenus anterior, while on the left side it crosses the first part of the artery close to the medial edge of the muscle. *Behind* and *below* the vessel are the pleura and lung; *above*, the brachial plexus of nerves. The subclavian vein lies below and in front of the artery, separated from it by the Scalenus anterior.

The third portion of the subclavian artery runs downwards and laterally from the lateral margin of the Scalenus anterior to the outer border of the first rib, where it becomes the axillary artery. This is the most superficial portion of the vessel, and is contained in the subclavian triangle (p. 593).

Relations.—*In front* of it are the skin, the superficial fascia, the Platysma, the supraclavicular nerves, and the deep cervical fascia. The external jugular vein crosses its medial part and receives the transverse scapular, transverse cervical, and anterior jugular veins, which frequently form a plexus in front of the artery. Behind the veins, the nerve to the Subclavius descends in front of the artery. The terminal part of the artery lies behind the clavicle and the Subclavius and is crossed by the transverse scapular vessels. The subclavian vein is in front of, and at a slightly lower level than, the artery. The lowest trunk of the brachial plexus lies *behind* the artery and intervenes between it and the Scalenus medius. *Above*, and to its *lateral side*, are the upper trunks of the brachial plexus, and the Omo-hyoideus. *Below*, it rests on the upper surface of the first rib.

Peculiarities.—The subclavian arteries vary in their origin, their course, and the height to which they rise in the neck.

The right subclavian sometimes arises from the innominate above the level of the sternoclavicular articulation; occasionally below the level of that joint. It may arise as a separate trunk from the arch of the aorta and may then be either its first, second, third, or last branch; in the majority of cases it is the first or last. When it is the first branch, it occupies the ordinary position of the innominate artery; when the second or third, it passes behind the right carotid; and when the last it arises from the left extremity of the arch, and ascends obliquely toward the right side, usually behind the trachea, oesophagus, and right carotid, sometimes between the oesophagus and trachea, to the upper border of the first rib, whence it follows its ordinary course. Occasionally the artery perforates the Scalenus anterior, more rarely it passes in front of that muscle. Sometimes the subclavian vein passes with the artery behind the Scalenus anterior. The artery may ascend as high as 4 cm. above the clavicle or may only reach the level of the upper border of the bone.

The left subclavian is occasionally joined at its origin with the left carotid. It is more deeply placed than the right subclavian in the first part of its course, and, as a rule, does not reach quite as high a level in the neck.

The posterior border of the Sternocleidomastoideus corresponds closely to the lateral border of the Scalenus anterior, so that the third portion of the artery, the part most accessible for operation, lies immediately lateral to the posterior border of the Sternocleidomastoideus.

Applied Anatomy.—An aneurysm may form on any part of the subclavian artery, except the intrathoracic portion of the left vessel, which is said never to be the seat of aneurysm. The most common site is the third portion (especially on the right side) on account of the greater exposure to injury and the greater amount of use of the right upper extremity. In this situation it may cause pressure on the brachial plexus, producing pain and numbness in the arm and fingers, with loss of power or paralysis of the muscles of these parts. Edema of the arm may result from pressure on the subclavian vein. The external jugular vein may become distended and varicose. The treatment is unsatisfactory, since proximal ligature cannot be undertaken with much chance of success. If constitutional treatment and direct pressure on the aneurysmal sac fail, the best treatment is excision of the sac, if it be small. In aneurysms of the first portion of this artery there is edema of the head and face, with lividity, congestion of the brain, and semiconsciousness from pressure on the internal jugular vein; and spasm of the Diaphragm from pressure on the phrenic nerve. The collateral circulation is so good that blocking of the subclavian artery by embolism or thrombosis often fails to give rise to any striking signs or symptoms, beyond occasional pains in the neck and shoulder and some degree of weakness and wasting in the muscles of the arm.

Compression of the subclavian artery may be required to control hemorrhage, and can be effectually applied in one situation only, viz. where the artery passes across the upper surface of the first rib. In order to compress the vessel in this situation, the shoulder should be depressed, and the surgeon grasping the side of the neck should press with his thumb in the angle formed by the posterior border of the Sternocleidomastoideus with the upper border of the clavicle, downwards, backwards, and medially against

SUBCLAVIAN ARTERY

the rib; if from any cause the shoulder cannot be sufficiently depressed, pressure may be made from before backwards, so as to compress the artery against the *Scalenus medius* and transverse process of the seventh cervical vertebra. In appropriate cases, a preliminary incision may be made through the cervical fascia, and the finger may be pressed down directly upon the artery.

In cases of through-and-through gunshot wounds about the clavicle the formation of an arteriovenous aneurysm, or direct communication between the subclavian artery and some neighbouring vein, is not rare. This enables arterial blood at high pressure to escape into the vein; the vein is distended thereby, with the production of a pulsatile swelling that can be felt above or below the clavicle. In addition a thrill can be felt and a loud rushing murmur can be heard in the neighbourhood of the swelling; both thrill and murmur are continuous, but more forcible during cardiac systole. Not infrequently these arteriovenous aneurysms call for relief by operation.

Ligature of the subclavian artery may be required in cases of wounds, or of aneurysm in the axilla, or in cases of aneurysm on the cardiac side of the point of ligature. The vessel is also ligatured as a preliminary measure to the complete interscapulothoracic amputation of the upper extremity, in which case the transverse scapular and transverse cervical arteries may, if found, be ligatured at the same time, making the 'fore-quarter' amputation an almost bloodless procedure.

The third part of the artery is that which is most favourable for an operation, on account of its being comparatively superficial and most remote from the origin of the large branches. In those cases where the clavicle is not displaced, this operation may be performed with comparative facility; but where the clavicle is pushed up by a large aneurysmal tumour in the axilla, the artery lies at a great depth from the surface, and this materially increases the difficulty. Under these circumstances, it becomes a matter of importance to consider the height to which this vessel reaches above the bone. In ordinary cases, its arch is about 1.25 cm. above the clavicle, occasionally as high as 4 cm., and sometimes so low as to be on a level with its upper border. If the clavicle be displaced, these variations will necessarily make the operation more or less difficult, according as the vessel is less or more accessible.

The procedure in the operation of tying the third portion of the subclavian artery is as follows: The patient being placed on a table in the supine position, with the head drawn over to the opposite side, and the shoulder depressed as much as possible, the skin should be pulled downwards over the clavicle, and an incision made through it, upon that bone, from the anterior border of the *Trapezius* to the posterior border of the *Sternocleidomastoideus*. The object in drawing the skin down is to avoid any risk of wounding the external jugular vein, which perforates the fascia above the clavicle, and cannot be drawn downwards with the skin. The soft parts are allowed to glide up, and the cervical fascia is divided; if the interval between the *Trapezius* and *Sternocleidomastoideus* be insufficient, a portion of one or both may be divided. The external jugular vein will now be seen towards the medial side of the wound; this and the transverse scapular and transverse cervical veins which extend to it should be held aside. If any large vein be at all in the way and exposed to injury, it should be tied in two places and divided. The transverse scapular artery should be avoided, and the *Omo-hyoideus* held aside if necessary. In the space beneath this muscle a deep layer of fascia and some connective tissue are divided, the lateral margin of the *Scalenus anterior* is felt for, and the finger being guided by it to the first rib, the pulsation of the subclavian artery will be felt as it passes over the rib. The sheath of the vessels having been opened, the aneurysm needle may then be passed around the artery from above downwards and medialwards so as to avoid including any of the branches of the brachial plexus, which in operations on the cadaver are not uncommonly mistaken for the vessel. If the clavicle be so raised by the tumour that the application of the ligature cannot be effected in this situation, the artery may be tied above the first rib, or even behind the *Scalenus anterior*.

The second part of the subclavian artery, the portion which rises highest in the neck, has been considered favourable for the application of the ligature when it is difficult to tie the artery in the third part of its course. There are, however, many objections to the operation in this situation. It is necessary to divide the *Scalenus anterior*, upon which lies the phrenic nerve, and at the medial side of which is situated the internal jugular vein; and a wound of either of these structures might lead to the most dangerous consequences. Again, the artery is in contact, below, with the pleura, which must also be avoided; and, lastly, the proximity of so many of its large branches arising medially to this point is a further objection to the operation. In cases, however, where the sac of an axillary aneurysm encroaches on the neck, it may be necessary to divide the lateral half or two-thirds of the *Scalenus anterior*, so as to place the ligature on the vessel at a greater distance from the sac. The operation is performed exactly in the same way as a ligature of the third portion, until the *Scalenus anterior* is exposed, when it is to be divided on a director (never to a greater extent than its lateral two-thirds), and it immediately retracts. This is therefore merely an extension of the operation for ligature of the third portion of the vessel.

In those cases of aneurysm of the axillary or subclavian artery which encroach upon the lateral portion of the *Scalenus anterior* to such an extent that a ligature cannot be applied in that situation, it may be deemed advisable, as a last resource, to tie the first

portion of the subclavian artery. On the left side, this operation is almost impracticable; the great depth of the artery from the surface, its intimate relation with the pleura, and its close proximity to the thoracic duct and to so many important veins and nerves, present a series of difficulties which it is next to impossible to overcome. On the right side, the operation is practicable, the main difficulty being the smallness of the interval which usually exists between the commencement of the vessel and the origin of the nearest branch. The operation is essentially similar to that described on p. 575 for ligature of the innominate artery. The exact position of the vagus, recurrent, and phrenic nerves and the sympathetic trunk should be borne in mind, and the ligature should be applied near the origin of the vertebral, in order to afford as much room as possible for the formation of a coagulum between the ligature and the origin of the vessel. It should be remembered that the right subclavian artery is occasionally deeply placed in the first part of its course, when it arises from the left side of the aortic arch, and passes in such cases behind the oesophagus, or between it and the trachea.

Collateral Circulation.—After ligature of the third part of the subclavian artery, the collateral circulation is established mainly by three sets of vessels, thus described in a dissection:

1. A posterior set, consisting of the transverse scapular artery and the descending ramus of the transverse cervical branch of the subclavian, anastomosing with the subscapular from the axillary.

2. A medial set, produced by the connexion of the internal mammary on the one hand, with the arteria intercostalis suprema and the lateral thoracic and subscapular arteries on the other.

3. A middle or axillary set, consisting of a number of small vessels derived from branches of the subclavian and, passing through the axilla, terminating either in the axillary artery, or some of its branches. This last set presented most conspicuously the peculiar character of newly formed or, rather, dilated arteries, being excessively tortuous, and forming a complete plexus.

The chief agent in the restoration of the axillary artery below the aneurysm was the subscapular artery, which communicated freely with the internal mammary, transverse scapular, and descending ramus of the transverse cervical arteries of the subclavian, from all of which it received so great an influx of blood as to dilate it to three times its natural size.*

When a ligature is applied to the first part of the subclavian artery, the collateral circulation is carried on by the following anastomoses: 1, between the superior and inferior thyroids; 2, the two vertebrals; 3, the internal mammary with the inferior epigastric and the aortic intercostals; 4, the costocervical with the aortic intercostals; 5, the a. profunda cervicalis with the descending branch of the occipital; 6, the scapular branches of the thyrocervical trunk with the branches of the axillary; and 7, the thoracic branches of the axillary with the aortic intercostals.

Branches.—The branches of the subclavian artery are:

Vertebral.

Thyrocervical.

Internal mammary.

Costocervical.

On the left side of the neck all four branches generally arise from the first portion of the artery; on the right side the costocervical trunk usually springs from the second portion. On both sides, the first three branches originate close together at the medial border of the Scalenus anterior.

1. The vertebral artery (fig. 621) arises from the upper and posterior part of the first portion of the subclavian artery. It ascends through the foramina in the transverse processes of the upper six cervical vertebrae,† winds behind the superior articular process of the atlas, enters the skull through the foramen magnum, and, at the lower border of the pons, unites with the vessel of the opposite side to form the basilar artery.

Relations.—The vertebral artery may be divided into four parts. The *first part* runs upwards and backwards between the Longus colli and the Scalenus anterior. In front of it are the internal jugular and vertebral veins, and it is crossed by the inferior thyroid artery; the left vertebral artery is crossed by the thoracic duct also. Behind it are the transverse process of the seventh cervical vertebra, the sympathetic trunk and its inferior cervical ganglion. The *second part* ascends through the foramina transversaria of the upper six cervical vertebrae, and is surrounded by a plexus of nerves derived from the inferior cervical sympathetic ganglion, and by a plexus of veins which unite to form the vertebral vein at the

* *Guy's Hospital Reports*, vol. i. 1836. Case of axillary aneurysm, in which Astley Cooper had tied the subclavian artery at the lateral edge of the Scalenus anterior, twelve years previously.

† The vertebral artery sometimes enters the foramen in the transverse process of the fifth vertebra, and has been seen entering that of the seventh vertebra.

lower part of the neck. It lies in front of the trunks of the cervical nerves, and runs an almost vertical course as far as the transverse process of the epistropheus, through which it runs upwards and lateralwards to the foramen transversarium of the atlas. The *third part* issues from the latter foramen on the medial side of the Rectus capitis lateralis, and curves backwards behind the superior articular process of the atlas, the anterior ramus of the first cervical nerve being on its medial side; it then lies in the groove on the upper surface of the posterior arch of the atlas, and enters the vertebral canal by passing beneath the posterior atlanto-occipital membrane. This part of the artery is covered by the Semispinalis capitis and is contained in the *suboccipital triangle*, (which is bounded by the Rectus capitis posterior major, the Obliquus superior, and the Obliquus inferior. The posterior division of the first cervical nerve lies between the artery and the posterior arch of the atlas.) The *fourth part* pierces the dura mater, ascends in front of the roots of the hypoglossal nerve, and inclines medialwards to the front of the medulla oblongata, where, at the lower border of the pons, it unites with the vessel of the opposite side to form the basilar artery.

The branches of the vertebral artery may be divided into two sets—those given off in the neck, and those within the cranium.

Cervical branches.

Spinal.
Muscular.

Cranial branches.

Meningeal.
Posterior spinal.
Anterior spinal.
Posterior inferior cerebellar.
Medullary.

Spinal branches enter the vertebral canal through the intervertebral foramina, and each divides into two branches. Of these, one passes along the roots of the nerves to supply the medulla spinalis and its membranes, anastomosing with the other arteries of the medulla spinalis; the other divides into an ascending and a descending branch, which unite with similar branches from the arteries above and below, so that two lateral anastomotic chains are formed on the posterior surfaces of the bodies of the vertebræ, near the attachment of the pedicles. From these anastomotic chains branches are supplied to the periosteum and the bodies of the vertebræ, and others communicate with similar branches from the opposite side; from these communications small twigs arise which join similar branches above and below, to form a central anastomotic chain on the posterior surfaces of the bodies of the vertebræ.

Muscular branches arise from the vertebral artery as it curves round the superior articular process of the atlas. They supply the deep muscles of the neck and anastomose with the occipital artery, and the ascending and deep cervical arteries.

One or two **meningeal branches** spring from the vertebral opposite the foramen magnum, ramify between the bone and dura mater in the cerebellar fossa, and supply the falx cerebelli.

The **posterior spinal artery** arises at the side of the medulla oblongata; it passes backwards, and then descends in front of the posterior roots of the spinal nerves, and is reinforced by a succession of small branches, which enter the vertebral canal through the intervertebral foramina; by means of these it is continued to the lower part of the medulla spinalis, and to the cauda equina. Branches from the posterior spinal arteries form a free anastomosis round the posterior roots of the spinal nerves, and communicate with the vessels of the opposite side. Near its origin each posterior spinal artery gives off an ascending branch, which ends at the side of the fourth ventricle.

The **anterior spinal artery** is a small branch, which arises near the termination of the vertebral; it descends in front of the medulla oblongata and unites with its fellow of the opposite side at the level of the foramen magnum. The single trunk, thus formed, descends on the front of the medulla spinalis, and is reinforced by a succession of small branches which enter the vertebral canal through the intervertebral foramina; these branches are derived from the vertebral, and from the ascending cervical of the inferior thyroid in the neck; from the intercostals in the thorax, and from the lumbar, ilio-lumbar, and lateral sacral arteries in the abdomen and pelvis. They unite, by means of ascending and descending branches, to form a single anterior median artery, which extends as far as the lower part of the medulla spinalis, and is continued as a slender twig on the filum terminale.

This vessel is placed in the pia mater along the anterior median fissure; it supplies that membrane, and the substance of the medulla spinalis, and sends off branches at its lower part to be distributed to the cauda equina.

The **posterior inferior cerebellar artery** (fig. 624), the largest branch of the vertebral, winds backwards round the upper part of the medulla oblongata, passing between the roots of the vagus and accessory nerves, over the restiform body to the under surface of the cerebellum, where it divides into a medial and a lateral branch. The medial branch runs backwards to the notch between the hemispheres of the cerebellum, while the lateral supplies the under surface of the hemisphere, as far as its lateral border, where it anastomoses with the anterior inferior cerebellar and the superior cerebellar branches of the basilar artery. Branches from this artery supply the chorioid plexus of the fourth ventricle.

The **medullary arteries** are several minute vessels which spring from the vertebral and its branches, and are distributed to the medulla oblongata.

The **basilar artery** (fig. 624), so named from its position at the base of the skull, is formed by the junction of the two vertebral arteries; it extends from the lower to the upper border of the pons, lying in a median groove, under cover of the arachnoid. It is placed between the two abducent nerves at the lower border of the pons, and between the two oculomotor nerves at the upper border, where it ends by dividing into the two posterior cerebral arteries.

Its branches, on either side, are the following:

Pontine.	Anterior inferior cerebellar.
Internal auditory.	Superior cerebellar.
	Posterior cerebral.

The **pontine branches** are a number of small vessels which come off at right angles from either side of the basilar artery, and supply the pons and adjacent parts of the brain.

The **internal auditory artery**, a long slender branch, arises from near the middle of the basilar artery; it accompanies the acoustic nerve through the internal acoustic meatus and is distributed to the internal ear.

The **anterior inferior cerebellar artery** passes backwards to the anterior part of the under surface of the cerebellum, and anastomoses with the posterior inferior cerebellar branch of the vertebral artery.

The **superior cerebellar artery** arises near the termination of the basilar. It passes lateralwards immediately below the oculomotor nerve which separates it from the posterior cerebral artery, winds round the cerebral peduncle close to the trochlear nerve, and, arriving at the upper surface of the cerebellum, divides into branches which ramify in the pia mater and anastomose with those of inferior cerebellar arteries. Several branches are given to the pineal body, the anterior medullary velum, and the tela chorioides of the third ventricle.

The **posterior cerebral artery** (figs. 624, 625, 626) is larger than the superior cerebellar artery, from which it is separated near its origin by the oculomotor nerve, and on the side of the mesencephalon by the trochlear nerve. Passing lateralwards, parallel to the superior cerebellar artery, and receiving the posterior communicating branch from the internal carotid, it winds round the cerebral peduncle, and reaches the tentorial surface of the cerebrum, where it breaks up into branches for the supply of the temporal and occipital lobes.

The branches of the posterior cerebral artery are divided into two sets, ganglionic and cortical:

Ganglionic	Posteromedial.	Cortical	Anterior temporal.
	Posterior chorioid.		Posterior temporal.
	Posterolateral.		Calcarine.
			Parieto-occipital.

Ganglionic.—The **posteromedial ganglionic branches** (fig. 627) are several small arteries which arise at the commencement of the posterior cerebral artery, along with similar branches from the posterior communicating, pierce the posterior perforated substance, and supply the medial surfaces of the thalami and the walls of the third ventricle. The **posterior chorioid branches** run forwards beneath the splenium of the corpus callosum and supply the tela chorioides of the third ventricle and end in the chorioid plexus of the lateral ventricle. The **posterolateral ganglionic branches** are small arteries which arise from the posterior cerebral artery.

after it has turned round the cerebral peduncle ; they supply a considerable portion of the thalamus.

Cortical.—The cortical branches are : the *anterior temporal*, distributed to the uncus and the anterior part of the fusiform gyrus ; the *posterior temporal*, to the fusiform and the inferior temporal gyri ; the *calcarine*, to the cuneus, gyrus lingualis, and the posterior part of the lateral surface of the occipital lobe ; and the *parieto-occipital*, to the cuneus and the præcuneus.

The internal mammary artery arises from the under surface of the first portion of the subclavian artery, opposite the thyrocervical trunk. It descends behind the cartilages of the upper six ribs at a distance of about 1.25 cm. from the lateral border of the sternum, and at the level of the sixth intercostal space divides into the *musculophrenic* and *superior epigastric* arteries.

Relations.—It runs at first downwards, forwards, and medialwards behind the sternal end of the clavicle, the internal jugular and innominate veins, and the first costal cartilage. As the artery enters the thorax, the phrenic nerve crosses from its lateral to its medial side. Below the first costal cartilage it descends almost vertically to its point of bifurcation. It is covered in front by the Pectoralis major, the cartilages of the upper six ribs and the intervening Intercostales interni and anterior intercostal membranes, and is crossed by the terminal portions of the upper six intercostal nerves. It is separated from the pleura, as far as the second or third costal cartilage, by a strong layer of fascia ; below this level, by the Transversus thoracis muscle. It is accompanied by a chain of lymph-glands and a pair of veins : the veins unite above to form a single vessel, which runs medially to the artery and ends in the corresponding innominate vein.

The branches of the internal mammary artery are :

Pericardiophrenic.
Anterior mediastinal.
Pericardial.

Sternal.
Intercostal.
Perforating.)

Musculophrenic.
Superior epigastric.

The pericardiophrenic artery (a. comes nervi phrenici) is a long slender branch which accompanies the phrenic nerve, between the pleura and pericardium, to the Diaphragm ; it gives branches to the pleura, pericardium and Diaphragm, and anastomoses with the musculophrenic and inferior phrenic arteries.

The anterior mediastinal arteries are small vessels, distributed to the areolar tissue and lymph-glands in the anterior mediastinal cavity, and to the remains of the thymus.

The pericardial branches supply the upper part of the anterior surface of the pericardium.

The sternal branches are distributed to the Transversus thoracis muscle, and to the posterior surface of the sternum.

The anterior mediastinal, pericardial, and sternal branches, together with some twigs from the pericardiophrenic, anastomose with branches from the intercostal and bronchial arteries, and form a *subpleural mediastinal plexus*.

The intercostal branches supply the upper five or six intercostal spaces. Two in number in each space, they pass lateralwards, one lying near the lower margin of the rib above, and the other near the upper margin of the rib below, and anastomose with the intercostal arteries from the aorta. They are at first situated between the pleura and the Intercostales interni, and then between the Intercostales interni and externi. They supply the Intercostales and send branches through the Intercostales externi to the Pectorales and the mamma.

The perforating branches emerge through the upper five or six intercostal spaces. They pierce the Pectoralis major, and curving lateralwards, supply that muscle and the skin. Those of the second, third, and fourth spaces give branches to the mamma, and during lactation are of large size.

The musculophrenic artery is directed obliquely downwards and lateralwards, behind the cartilages of the false ribs ; it perforates the Diaphragm at the eighth or ninth costal cartilage, and ends, considerably reduced in size, opposite the last intercostal space. It gives off intercostal branches to the seventh, eighth, and ninth intercostal spaces ; these diminish in size as the spaces decrease in length, and are distributed in a manner similar to the intercostals from the internal mammary. The musculophrenic also gives branches to the lower part of the pericardium, the Diaphragm, and the abdominal muscles.

The superior epigastric artery descends through the interval between the costal and xiphoid origins of the Diaphragm, and enters the sheath of the Rectus abdominis, at first lying behind the muscle, and then perforating and supplying it, and anastomosing with the inferior epigastric artery from the external iliac. Branches

perforate the sheath of the Rectus, and supply the muscles and skin of the abdomen, and a small branch passes in front of the xiphoid process and anastomoses with the artery of the opposite side. The superior epigastric artery also gives some twigs to the Diaphragm, while from the artery of the right side small branches extend into the falciform ligament of the liver and anastomose with the hepatic artery.

Applied Anatomy.—The internal mammary artery is liable to be wounded in stabs of the chest-wall and in the operation of paracentesis pericardii (p. 553). It is most easily reached by a transverse incision in the second intercostal space.

3. The **thyrocervical trunk** (thyreoid axis) (fig. 628), a short thick trunk, arises from the front of the first portion of the subclavian artery, close to the medial border of the Scalenus anterior, and divides almost immediately into three branches, the *inferior thyreoid*, *transverse scapular*, and *transverse cervical*.

The **inferior thyreoid artery** runs upwards in front of the vertebral artery and Longus colli; it then turns medialwards behind the carotid sheath and its contents, and also behind the sympathetic trunk, the middle cervical ganglion of which rests upon the vessel; it finally descends to the lower border of the lateral lobe of the thyreoid gland. The recurrent nerve runs upwards generally behind, but occasionally in front of, the artery.

The branches of the inferior thyreoid are :

Muscular.	Inferior laryngeal.	Œsophageal.
Ascending cervical.	Tracheal.	Glandular.

The **muscular branches** supply the depressors of the hyoid bone, and the Longus colli, Scalenus anterior, and Constrictor pharyngis inferior.

The **ascending cervical artery** is a small branch which arises from the inferior thyreoid as that vessel is passing behind the carotid sheath; it ascends on the anterior tubercles of the transverse processes of the cervical vertebræ in the interval between the Scalenus anterior and Longus capitis. It gives twigs to the muscles of the neck, and sends one or two spinal branches into the vertebral canal through the intervertebral foramina to be distributed to the medulla spinalis and its membranes, and to the bodies of the vertebræ, in the same manner as the spinal branches from the vertebral artery. It anastomoses with the vertebral, ascending pharyngeal and occipital arteries.

The **inferior laryngeal artery** ascends upon the trachea in company with the recurrent nerve; it enters the larynx under the lower border of the Constrictor pharyngis inferior, and supplies its muscles and mucous membrane, anastomosing with the artery from the opposite side, and with the superior laryngeal branch of the superior thyreoid artery.

The **tracheal branches** are distributed to the trachea, and anastomose below with the bronchial arteries.

The **œsophageal branches** supply the œsophagus, and anastomose with the œsophageal branches of the thoracic aorta.

The **glandular branches** consist of an inferior and an ascending branch; they supply the posterior and inferior parts of the thyreoid gland, and anastomose with the superior thyreoid artery and with the opposite inferior thyreoid artery.

The **transverse scapular artery** (suprascapular artery) passes at first downwards and lateralwards across the Scalenus anterior and phrenic nerve, under cover of the Sternocleidomastoideus; it then crosses the subclavian artery and the brachial plexus, and runs behind and parallel with the clavicle and Subclavius, and beneath the inferior belly of the Omohyoideus, to the superior border of the scapula; it passes over the superior transverse ligament of the scapula, which separates it from the suprascapular nerve, and enters the supraspinatous fossa (fig. 629). In this situation it lies close to the bone, and supplies branches to the Supraspinatus. It then descends behind the neck of the scapula, through the great scapular notch and beneath the inferior transverse ligament, to reach the infraspinatous fossa, where, under cover of the Infraspinatus, it anastomoses with the scapular circumflex artery and the descending branch of the transverse cervical artery. Besides distributing branches to the Sternocleidomastoideus, Subclavius, and neighbouring muscles, it gives off a *suprasternal branch*, which crosses over the sternal end of the clavicle to the skin of the upper part of the chest; and an *acromial branch*, which pierces the Trapezius and supplies the skin over the acromion, anastomosing with the thoraco-acromial artery. As the transverse

scapular artery passes over the superior transverse ligament of the scapula, it sends a branch into the subscapular fossa, where it ramifies beneath the Subscapularis, and anastomoses with the subscapular artery and with the descending branch of the transverse cervical artery. The transverse scapular artery also sends articular branches to the acromioclavicular and shoulder-joints, and nutrient arteries to the clavicle and scapula.

The **transverse cervical artery** (a. transversa colli) lies at a higher level than the transverse scapular; it passes behind the Omohyoideus and runs transversely above the posterior belly of that muscle, to the anterior margin of the Levator scapulæ, where it divides into an ascending and a descending branch. It crosses in front of the phrenic nerve and the Scalenii, and in front of or between the divisions of the brachial plexus, and is covered by the Platysma and Sternocleidomastoideus.

The **ascending branch** (superficial cervical artery) ascends beneath the anterior part of the Trapezius, distributing branches to it and to the neighbouring muscles and lymph-glands in the neck, and anastomosing with the superficial branch of the descending ramus of the occipital artery.

The **descending branch** (posterior scapular artery) (fig. 629) passes beneath the Levator scapulæ to the medial angle of the scapula, and then descends under cover of the Rhomboidei along the vertebral border of the scapula as far as the inferior angle. It supplies the Rhomboidei, Latissimus dorsi and Trapezius, and anastomoses with the transverse scapular and subscapular arteries, and with the posterior branches of some of the intercostal arteries.

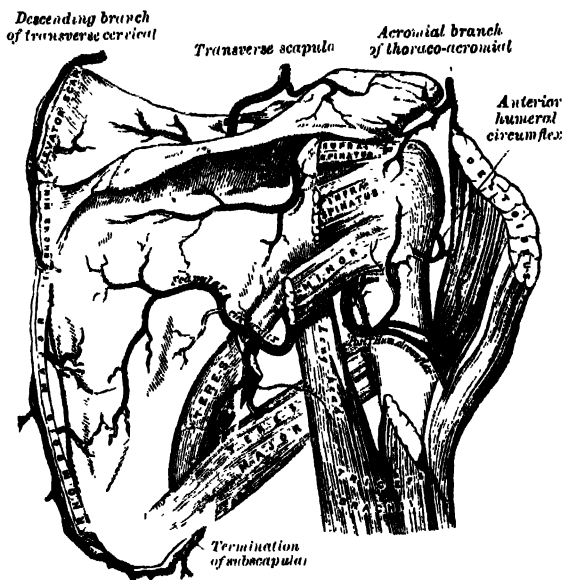
Peculiarities.—In a large proportion of cases the ascending branch (superficial cervical artery) arises directly from the thyrocervical trunk, and the descending branch (posterior scapular artery) from the third, more rarely from the second, part of the subclavian.

4. The **costocervical artery** (superior intercostal artery) (fig. 621) arises from the posterior aspect of the second part of the subclavian artery on the right side, but from the first part of the artery on the left side. It passes backwards above the cupola of the pleura to the neck of the first rib, and divides into the *arteria intercostalis suprema* and the *arteria cervicalis profunda*.

The **arteria intercostalis suprema** descends behind the pleura in front of the necks of the first and second ribs, and anastomoses with the first aortic intercostal artery. As it crosses the neck of the first rib it lies medially to the anterior division of the first thoracic nerve, and laterally to the first thoracic ganglion of the sympathetic trunk. In the first intercostal space, it gives off a branch which is distributed in a manner similar to the distribution of the aortic intercostals. The branch for the second intercostal space usually joins with one from the first aortic intercostal artery; this branch is not constant, but is more commonly found on the right side; when absent, its place is supplied by an intercostal branch from the aorta.

The **arteria cervicalis profunda** arises, in most cases, from the costocervical trunk, and is analogous to the posterior branch of an aortic intercostal artery: occasionally it is a separate branch from the subclavian artery. Passing backwards above the eighth cervical nerve and between the transverse process of the seventh cervical vertebra and the neck of the first rib, it ascends on the back of the neck, between

FIG. 629.—The scapular and circumflex arteries.



the Semispinales capitis and colli, as high as the second cervical vertebra, supplying the adjacent muscles, and anastomosing with the deep division of the descending branch of the occipital artery, and with branches of the vertebral artery. It gives off a spinal twig which enters the vertebral canal through the foramen between the seventh cervical and first thoracic vertebræ.



The **axilla** is a pyramidal space, situated between the upper part of the lateral wall of the chest and the medial side of the arm.

Boundaries.—The *apex*, which is directed upwards towards the root of the neck, corresponds to the interval between the outer border of the first rib, the superior border of the scapula, and the posterior surface of the clavicle; through it the axillary vessels and nerves enter the space from the neck. The *base*, directed downwards, is broad at the chest but narrow and pointed at the arm; it is formed by the skin and a thick layer of fascia, the *axillary fascia*, extending between the lower border of the Pectoralis major in front, and the lower border of the Latissimus dorsi behind. The *anterior wall* is formed by the Pectorales major and minor, the former covering the whole of this wall, the latter only its central part. The space between the upper border of the Pectoralis minor and the clavicle is occupied by the coracoclavicular fascia (costocoracoid membrane). The *posterior wall* is formed by the Subscapularis above, the Teres major and Latissimus dorsi below. On the *medial side* are the first four ribs with their corresponding Intercostales, and the upper part of the Serratus anterior. On the *lateral side*, where the anterior and posterior walls converge, the space is narrow, and bounded by the humerus, the Coracobrachialis, and the Biceps brachii.

Contents.—It contains the axillary vessels, and the infraclavicular part of the brachial plexus of nerves, with their branches, some branches of the intercostal nerves, and a large number of lymph-glands, together with a quantity of fat and loose areolar tissue. The axillary vessels and the brachial plexus of nerves run from the apex to the base along the lateral wall of the axilla; they are placed nearer to the anterior than to the posterior wall, the axillary vein lying to the thoracic side of the axillary artery and partially concealing it. The thoracic branches of the axillary artery are in contact with the Pectorales, and along the lower margin of the Pectoralis minor the lateral thoracic artery passes to the side of the thorax. The subscapular vessels and nerves descend on the posterior wall in contact with the lower margin of the Subscapularis; the scapular circumflex vessels wind round the lateral border of this muscle, and the posterior humeral circumflex vessels and the axillary nerve curve backwards close to the neck of the humerus. No vessel of any importance exists along the medial or thoracic side, the upper part of the space being crossed merely by a few small branches from the highest thoracic artery. The long thoracic nerve descends on the surface of the Serratus anterior, to which it is distributed; and the intercostobrachial nerve perforates the upper and anterior part of this wall, and passes across the axilla to the medial side of the arm.

The position and arrangement of the lymph-glands are described on pp. 719, 720.

Applied Anatomy.—The axilla is a space of considerable surgical importance. Its vessels and nerves may be the seat of injury or disease: its lymph-glands may require removal; its loose connective and adipose tissue may be readily infiltrated with blood or inflammatory exudation; and the space may be the seat of rapidly growing tumours. Moreover, its base is covered by thin skin, which is well supplied with sebaceous and sweat glands, and is frequently the seat of small abscesses and boils.

Penetrating wounds in the axilla are sometimes accompanied by extensive hæmorrhage, either from wound of the main vessels, or of one of the large branches of the axillary artery, e.g. the lateral thoracic or the subscapular. Where the blood cannot find an easy exit it collects in the space and forms a large swelling which projects in the floor of the axilla and also bulges forwards the Pectoralis major. The treatment consists in freely opening up the cavity, searching for and securing the bleeding vessel.

When suppuration occurs in the axilla, the arrangement of the fasciæ plays a very important part in the direction which the pus takes. As described on p. 488, the coraco-

clavicular fascia, after covering the space between the clavicle and the upper border of the Pectoralis minor, splits to enclose this muscle, and at its lower border is incorporated with the axillary fascia at the anterior fold of the axilla. Suppuration may take place either superficial to or beneath this layer of fascia; that is, either between the Pectorales or behind the Pectoralis minor: in the former case, the abscess would point either at the border of the anterior axillary fold, or in the groove between the Deltoides and the Pectoralis major; in the latter, the pus would have a tendency to surround the vessels and nerves, and ascend into the neck, that being the direction in which there is least resistance. Its progress towards the surface is prevented by the axillary fascia; its progress backwards, by the insertion of the Serratus anterior; forwards, by the coracoclavicular fascia; medialwards, by the wall of the thorax; and lateralwards, by the upper limb. The pus in these cases, after extending into the neck, has been known to spread through the superior opening of the thorax into the mediastinal cavity. Instances have been recorded where the pus found its way along the vessels into the arm.

When opening an axillary abscess, the knife should be entered in the floor of the axilla, midway between the anterior and posterior margins and near the thoracic side of the space. After an incision has been made through the skin and fascia, it is well to use a director and dressing forceps in the manner directed by Hilton.

The relations of the vessels and nerves in the several parts of the axilla are important, for it is the almost universal plan to remove the lymph-glands from the axilla in operating for cancer of the breast. In performing such an operation, it is necessary to proceed with much caution in the direction of the lateral wall and apex of the space, as here the axillary vessels are in danger of being wounded. The subscapular, scapular circumflex, and posterior humeral circumflex vessels on the posterior wall and the thoracic branches along the anterior wall must be avoided. In clearing out the axilla, the axillary vein should first be defined and traced up to the apex of the space by means of a director. In order to do this the sternocostal portion of the Pectoralis major, together with the whole of the Pectoralis minor, must be divided and turned aside, by which means the surgeon is enabled to clear out the axillary cavity more thoroughly. When the apex of the space is reached all the fat and the lymph-glands must be carefully removed and the whole axilla cleared by separating the tissues from above downwards from the vessels, and from the medial and posterior walls, so that when the proceeding is completed the axilla is emptied of all its contents except the main vessels and nerves.

✓ AXILLARY ARTERY (fig. 630)

The axillary artery, the continuation of the subclavian, commences at the outer border of the first rib, and ends at the lower border of the tendon of the Teres major muscle, beyond which the artery takes the name of brachial. Its direction varies with the position of the limb: thus the vessel is nearly straight when the arm is directed at right angles with the trunk, concave upwards when the arm is elevated above this, and convex upwards and lateralwards when the arm lies by the side of the trunk. The first part of the artery is deeply situated, but its terminal part is superficial and is covered only by the skin and fasciæ. The Pectoralis minor muscle crosses the vessel and divides it into three portions; the first part is proximal to, the second behind, and the third distal to the muscle.

The first portion of the axillary artery is covered *anteriorly* by the clavicular portion of the Pectoralis major and by the coracoclavicular fascia, and is crossed by the lateral anterior thoracic nerve, and the thoraco-acromial and cephalic veins; *posterior* to it are the first intercostal space and Intercostalis externus, the first and second digitations of the Serratus anterior, the long thoracic and medial anterior thoracic nerves, and the medial cord of the brachial plexus; on its *lateral side* are the lateral and posterior cords of the brachial plexus; on its *medial side* is the axillary vein which overlaps the artery. The artery is enclosed, together with the axillary vein and the brachial plexus, in a fibrous sheath, the *axillary sheath*, continuous above with the deep cervical fascia.

The second portion of the axillary artery is covered, *anteriorly*, by the Pectorales major and minor; *posterior* to it are the posterior cord of the brachial plexus and some areolar tissue which intervene between it and the Subscapularis; on the *medial side* is the axillary vein, separated from the artery by the medial cord of the brachial plexus and the medial anterior thoracic nerve; on the *lateral side* is the lateral cord of the brachial plexus. The cords of the brachial plexus thus surround the artery on three sides, and separate it from direct contact with the vein and adjacent muscles.

The third portion of the axillary artery extends from the lower border of the Pectoralis minor to the lower border of the Teres major. *In front*, it is covered

than to the posterior fold of the axilla. After dissecting through the areolar tissue and fascia, the median nerve and axillary vein are exposed; these are retracted and, the elbow being bent so as to relax the structures, the ligature is applied. This portion of the artery is occasionally crossed by a muscular slip, the *axillary arch* (p. 480), derived from the *Latissimus dorsi*.

The *first portion* of the axillary artery may be tied in cases of aneurysm encroaching so far upwards that a ligature cannot be applied to the lower part of the artery. Its performance is attended with much difficulty and danger. The student will remark that, in this situation, it would be necessary to divide a thick muscle, and, after incising the coracoclavicular fascia, the artery would be exposed at the bottom of a more or less deep space, with the cephalic and axillary veins in such relation with it as must render the application of a ligature to it particularly hazardous. Under such circumstances, it is an easier and, at the same time, a more advisable operation, to tie the third part of the subclavian artery. The first part of the axillary artery can be best secured by a curved incision with the convexity downwards from a point 1.25 cm. lateral to the sternoclavicular joint to a point 1.25 cm. on the medial side of the coracoid process. The limb is to be well abducted and the head inclined to the opposite side, and the incision carried through the superficial structures, care being taken of the cephalic vein at the lateral end of the incision. The clavicular origin of the *Pectoralis major* is then divided in the whole extent of the wound. The arm is now brought to the side, and the upper edge of the *Pectoralis minor* defined and drawn downwards. The coracoclavicular fascia is divided, and the axillary sheath exposed; this is to be opened with especial care on account of the vein overlapping the artery. The needle should be passed from below, so as to avoid wounding the vein.

Collateral Circulation.—If the axillary artery be tied above the origin of the thoraco-acromial artery, the collateral circulation will be carried on by the same branches as after the ligature of the third part of the subclavian (p. 606); if at a lower point, between the thoraco-acromial and the subscapular arteries, the latter vessel, by its free anastomoses with the transverse scapular and transverse cervical arteries, will become the chief agent in carrying on the circulation; the lateral thoracic artery, if it be below the ligature, will materially contribute by its anastomoses with the intercostal and internal mammary arteries. If the ligature be applied below the origin of the subscapular artery, it will most probably also be below the origins of the two humeral circumflex arteries: the chief agents in restoring the circulation will then be the subscapular and the two humeral circumflex arteries anastomosing with the *arteria profunda brachii*.

The branches of the axillary artery are :

From first part 1. Highest thoracic. From second part { 2. Thoraco-acromial.
3. Lateral thoracic.
From third part { 4. Subscapular.
5. Anterior humeral circumflex.
6. Posterior humeral circumflex.

1. The **highest thoracic artery** (superior thoracic artery) is a small vessel, which arises from the axillary artery near the lower border of the *Subclavius* muscle, but may take origin from the thoraco-acromial artery. Running forwards and medialwards along the upper border of the *Pectoralis minor*, it passes between it and the *Pectoralis major* to the side of the chest. It supplies branches to these muscles, and to the thoracic wall, and anastomoses with the internal mammary and intercostal arteries.

2. The **thoraco-acromial artery** (thoracic axis) is a short trunk, which arises from the front of the axillary artery, its origin being generally overlapped by the upper edge of the *Pectoralis minor*. Passing forwards at the upper border of this muscle, it pierces the coracoclavicular fascia and divides into four branches—pectoral, acromial, clavicular, and deltoid. The *pectoral branch* descends between the two *Pectorales*, and is distributed to them and to the mamma, anastomosing with the intercostal branches of the internal mammary artery and with the lateral thoracic artery. The *acromial branch* runs lateralwards over the coracoid process and under the *Deltoideus*, to which it gives branches; it then pierces that muscle and ends on the acromion in an arterial network formed by branches from the transverse scapular, thoraco-acromial, and posterior humeral circumflex arteries. The *clavicular branch* runs upwards and medialwards between the clavicular part of the *Pectoralis major* and the coracoclavicular fascia; it gives branches to the sternoclavicular joint, and to the *Subclavius*. The *deltoid (humeral) branch*, often arising with the acromial, crosses over the *Pectoralis minor* and runs with the cephalic vein between the *Pectoralis major* and *Deltoideus*, giving branches to both muscles.

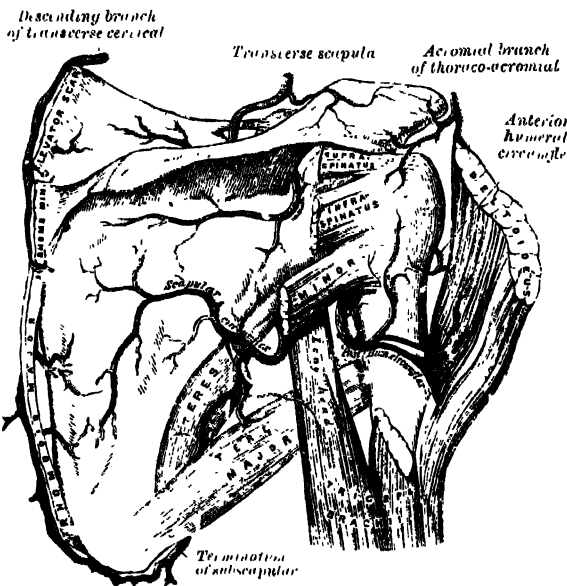
3. The **lateral thoracic artery** (long thoracic artery) follows the lower border of the *Pectoralis minor* to the side of the chest, supplies the *Serratus anterior* and

the Pectorales, and sends branches to the axillary lymph-glands, and to the Subscapularis; it anastomoses with the internal mammary, subscapular, and intercostal arteries, and with the pectoral branch of the thoraco-acromial artery. In the female, the lateral thoracic artery is large, and gives off an *external mammary branch* which turns round the free edge of the Pectoralis major and supplies the mamma.

4. The **subscapular artery**, the largest branch of the axillary artery, arises at the lower border of the Subscapularis, which it follows to the inferior angle of the scapula, where it anastomoses with the lateral thoracic and intercostal arteries and with the descending branch of the transverse cervical artery, and ends in the neighbouring muscles and adjacent part of the chest-wall. In the lower part of its course it is accompanied by the thoraco-dorsal nerve; about 4 cm. from its origin it gives off the *scapular circumflex artery*.

The **scapular circumflex artery** (arteria dorsalis scapulæ) is generally larger than the continuation of the subscapular. It curves round the axillary border of the scapula, traversing the triangular space between the Subscapularis above, the Teres major below, and the long head of the Triceps laterally (fig. 631); it enters the infraspinatus fossa under cover of the Teres minor, and anastomoses with the transverse scapular artery and the descending branch of the transverse cervical artery. It gives off two branches: one (*infrascapular*) enters the subscapular

FIG. 631.—The scapular and circumflex arteries.



fossa beneath the Subscapularis, which it supplies, and anastomoses with the transverse scapular artery and the descending branch of the transverse cervical artery; the other is continued along the axillary border of the scapula, between the Teres major and the Teres minor, and at the dorsal surface of the inferior angle anastomoses with the descending branch of the transverse cervical artery. In addition to these, small branches are distributed to the posterior part of the Deltoideus and the long head of the Triceps brachii, anastomosing with an ascending branch of the arteria profunda brachii.

5. The **anterior humeral circumflex artery** (fig. 631), a small artery, arises from

the lateral side of the axillary artery at the lower border of the Subscapularis. It runs horizontally, beneath the Coracobrachialis and short head of the Biceps brachii, in front of the neck of the humerus. On reaching the intertubercular sulcus, it gives off a branch which ascends in the sulcus to supply the head of the humerus and the shoulder-joint. The trunk of the vessel is then continued onwards beneath the long head of the Biceps brachii and the Deltoideus, and anastomoses with the posterior humeral circumflex artery.

6. The **posterior humeral circumflex artery** (fig. 631), considerably larger than the anterior, arises from the axillary artery at the lower border of the Subscapularis, and runs backwards with the axillary nerve through the quadrangular space bounded by the Subscapularis and Teres minor above, the Teres major below, the long head of the Triceps brachii medially, and the surgical neck of the humerus laterally. It winds round the neck of the humerus and is distributed to the Deltoideus and shoulder-joint, anastomosing with the anterior humeral circumflex artery and arteria profunda brachii.

Peculiarities.—The branches of the axillary artery vary considerably in different subjects. Occasionally the subscapular, humeral circumflex, and profunda arteries arise

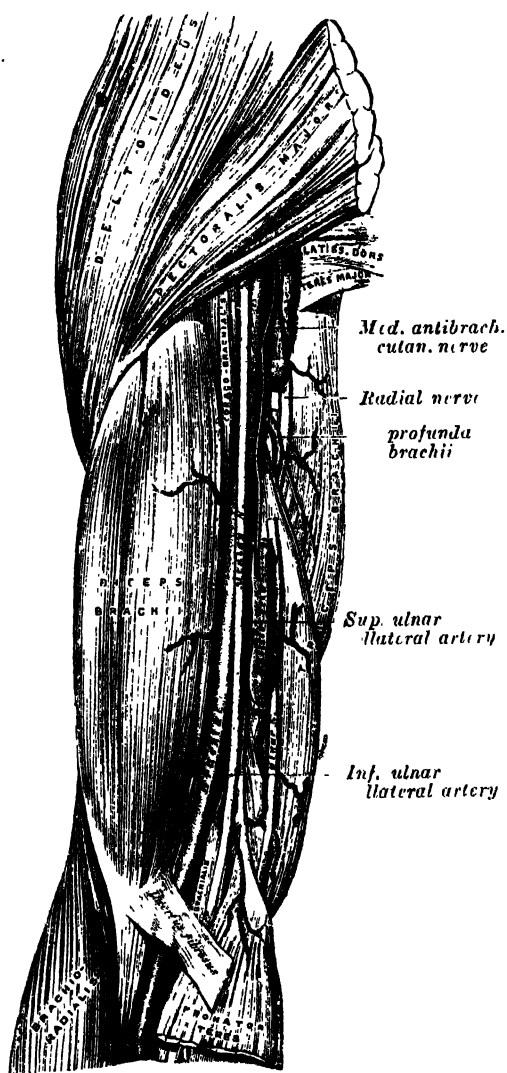
from a common trunk, and when this occurs the branches of the brachial plexus surround this trunk instead of the main vessel. Sometimes the axillary artery divides into the radial and ulnar arteries, and occasionally it gives origin to the volar interosseous artery of the forearm.

BRACHIAL ARTERY (fig. 632)

The **brachial artery** commences at the distal margin of the tendon of the *Teres major*, runs straight down the arm, and ends about 1 cm. below the bend of the elbow by dividing into the *radial* and *ulnar arteries*. At first it lies medially to the humerus; but as it descends it gradually inclines to front of the bone, and at the bend of the elbow lies midway between its two epicondyles.

Relations.—The artery is superficial throughout its entire extent, being covered by the skin and the superficial and deep fasciæ; the *lactus fibrosus* (bicipital fascia) lies in front of it opposite the elbow and separates it from the median cubital vein; the median nerve crosses from its lateral to its medial side opposite the insertion of the *Coracobrachialis*. *Posteriorly*, it is separated from the long head of the *Triceps brachii* by the radial nerve and *arteria profunda brachii*. It then lies upon the medial head of the *Triceps brachii*, next upon the insertion of the *Coracobrachialis*, and lastly on the *Brachialis*. *Laterally*, it is in relation above with the median nerve and the *Coracobrachialis*, below with the *Biceps brachii*, the two muscles overlapping the artery to a considerable extent. *Medially*, its upper half is in relation with the medial antibrachial cutaneous and ulnar nerves, its lower half with the median nerve. The basilic vein lies on its medial side, but is separated from it in the lower part of the arm by the deep fascia. The artery is closely accompanied by two *venæ comitantes* which are connected at intervals by short transverse branches.

FIG. 632.—The brachial artery.



THE CUBITAL FOSSA

At the bend of the elbow the brachial artery sinks deeply into a triangular interval, the *cubital fossa*. The base of the triangle is represented by a line connecting the two humeral epicondyles; the sides are formed by the medial edge of the *Brachioradialis* and the lateral margin of the *Pronator teres*; the floor consists of the *Brachialis* and *Supinator*. This fossa contains the terminal part of the brachial artery, its accompanying veins, the radial and ulnar arteries, the median and radial nerves, and the tendon of the *Biceps brachii*. The brachial artery occupies the middle of the fossa, and divides opposite the

neck of the radius into the radial and ulnar arteries; it is covered, *in front*, by the skin, the superficial fascia, and the median cubital vein, the last being separated from the artery by the *lacertus fibrosus*. *Behind* it is the *Brachialis*, which separates it from the elbow-joint. The median nerve lies close to the medial side of the artery above, but is separated from it below by the ulnar head of the *Pronator teres*. The tendon of the *Biceps brachii* is lateral to the artery; the radial nerve rests upon the *Supinator*, and is concealed by the *Brachioradialis*.

Peculiarities.—The brachial artery, accompanied by the median nerve, may leave the medial border of the *Biceps brachii*, and descend towards the medial epicondyle of the humerus; in such cases it usually passes behind the *supracondylar process* of the humerus, from which a fibrous arch is in most cases thrown over the artery; it then runs beneath or through the substance of the *Pronator teres*, to the bend of the elbow. This variation bears considerable analogy with the normal condition of the artery in some of the *canivora*, and has been referred to in the description of the humerus (p. 277 *). Occasionally, the upper part of the artery splits into two trunks which reunite. Frequently it divides at a higher level than usual, and the vessels concerned in this high division are three: viz. radial, ulnar, and interosseous arteries. Most frequently the radial is given off high up, the other limb of the bifurcation consisting of the ulnar and interosseous; in some instances the ulnar originates above the ordinary level, and the radial and interosseous form the other limb of the division; occasionally the interosseous arises high up.

Sometimes long slender vessels, termed *vasa aberrantia*, connect the brachial or the axillary artery with one or other of the arteries of the forearm. These vessels usually join the radial.

The brachial artery is occasionally concealed in some part of its course, by muscular or tendinous slips derived from the *Coracobrachialis*, *Biceps brachii*, *Brachialis*, or *Pronator teres*.

Applied Anatomy.—In spite of the fact that the brachial artery is very superficial and but little protected by surrounding parts, it is seldom wounded. This, no doubt, is due to its situation on the medial side of the arm, which is little exposed to injury.

Compression of the brachial artery is required in cases of amputation and some other operations in the arm and forearm, and may be effected in almost any part of the course of the artery. If pressure be made in the upper part of the arm, it should be directed lateralwards; if in the lower part, backwards, as the artery lies on the medial side of the humerus above, and in front of it below. The most favourable situation is about the middle of the arm, where the artery lies on the tendon of the *Coracobrachialis* on the medial surface of the humerus.

Ligature of the brachial artery may be required in cases of wound of the vessel, and in some cases of wound of the volar arch. It is also sometimes necessary in cases of aneurysm of the brachial, radial, ulnar, or interosseous arteries. The artery may be secured in any part of its course. The chief guides in determining its position are the surface markings produced by the medial margins of the *Coracobrachialis* and *Biceps brachii*, and the known course of the vessel; its pulsation should be carefully felt for before any operation is performed, as the vessel occasionally deviates from its usual position. It is essential in applying a ligature to this vessel that the arm should be held away from the side of the body, and supported only from the elbow, for if the arm be allowed to rest on any firm structure the *Triceps brachii* is pressed forwards and overlaps the vessel, thus making the operation much more difficult.

In the upper third of the arm the brachial artery may be exposed in the following manner. The patient being placed supine, the limb should be raised from the side, and the hand supinated. An incision about 5 cm. in length is made on the medial side of the *Coracobrachialis*, and the subjacent fascia cautiously divided, so as to avoid wounding the medial antibrachial cutaneous nerve or basilic vein, as the latter sometimes runs on the surface of the artery as high as the axilla. The fascia having been divided, it should be remembered that the ulnar nerve and the medial antibrachial cutaneous nerve lie on the medial side of the artery, the median nerve on the lateral side but occasionally superficial to the artery in this situation, and that the *venae comitantes* are also in relation with the vessel, one on either side. These being carefully separated, the aneurysm needle should be passed round the artery from the medial side.

In the case of a high division, the two arteries are usually placed side by side; and if they are exposed in an operation, the surgeon should endeavour to ascertain, by alternately pressing on each vessel, which is connected with the wound or aneurysm; when a ligature may be applied accordingly; if pulsation or hæmorrhage ceases only when both vessels are compressed, both must be tied.

In the middle of the arm the brachial artery may be exposed by making an incision along the medial margin of the *Biceps brachii*. The forearm is then bent so as to relax this muscle which should be drawn aside, and the fascia carefully divided, when the median nerve will be exposed lying upon (sometimes behind) the artery; the nerve being drawn medialwards and the muscle lateralwards, the artery should be separated from its

accompanying veins and secured. In this situation the superior ulnar collateral artery (*inferior profunda artery*) may be mistaken for the main trunk, especially if enlarged from the collateral circulation having become established; this may be avoided by directing the incision towards the *Biceps brachii*, rather than towards the *Triceps brachii*.

The lower part of the brachial artery is of interest on account of the relation it bears to the veins most commonly opened in venesection. Of these vessels, the median cubital vein (median basilic vein) is the largest and most prominent, and consequently the one usually selected for the operation. This vein runs parallel with the brachial artery, from which it is separated by the *lacertus fibrosus* (*bicipital fascia*), and care should be taken, in opening the vein, not to carry the incision so deep as to endanger the artery.

Collateral Circulation.—After the application of a ligature to the brachial artery in the upper third of the arm, the circulation is carried on by branches from the humeral circumflex and subscapular arteries anastomosing with ascending branches from the *arteria profunda brachii*. If the artery be tied below the origins of the *arteria profunda brachii* and superior ulnar collateral artery, the circulation is maintained by the branches of these two arteries anastomosing with the inferior ulnar collateral artery, and with the radial, the ulnar, and the interosseous recurrent arteries.

The branches of the brachial artery are :

1. *Arteria profunda brachii*.
2. Nutrient.
3. Superior ulnar collateral.
4. Inferior ulnar collateral.
5. Muscular.

1. The *arteria profunda brachii* (*superior profunda artery*) is a large vessel which arises from the medial and posterior part of the brachial artery, just distal to the lower border of the *Teres major*. It follows closely the radial nerve, running at first backwards between the medial and lateral heads of the *Triceps brachii*, then along the sulcus for the radial nerve, where it is covered by the lateral head of the *Triceps brachii*, to the lateral side of the arm; there it pierces the lateral intermuscular septum, and, descending between the *Brachioradialis* and the *Brachialis* to the front of the lateral epicondyle of the humerus, ends by anastomosing with the radial recurrent artery. It gives branches to the *Deltoides* and to the muscles between which it lies; it supplies an occasional *nutrient artery* which enters the humerus behind the deltoid tuberosity. A branch ascends between the long and lateral heads of the *Triceps brachii* to anastomose with the posterior humeral circumflex artery; a *middle collateral branch* descends in the medial head of the *Triceps brachii* with the nerve which supplies the *Anconæus* muscle, and assists in forming the anastomosis above the olecranon; and, lastly, a *radial collateral branch* (posterior branch of superior profunda) runs down behind the lateral intermuscular septum to the back of the lateral epicondyle of the humerus, where it anastomoses with the interosseous recurrent and the inferior ulnar collateral arteries.

2. The *nutrient artery* of the humerus arises about the middle of the arm and enters the nutrient canal near the insertion of the *Coracobrachialis*.

3. The *superior ulnar collateral artery* (*inferior profunda artery*), of small size, arises from the brachial a little below the middle of the arm; it frequently springs from the upper part of the *arteria profunda brachii*. It accompanies the ulnar nerve, pierces the medial intermuscular septum, descends between the medial epicondyle and olecranon, and ends under the *Flexor carpi ulnaris* by anastomosing with the posterior ulnar recurrent and inferior ulnar collateral arteries. It sometimes sends a branch in front of the medial epicondyle, to anastomose with the anterior ulnar recurrent artery.

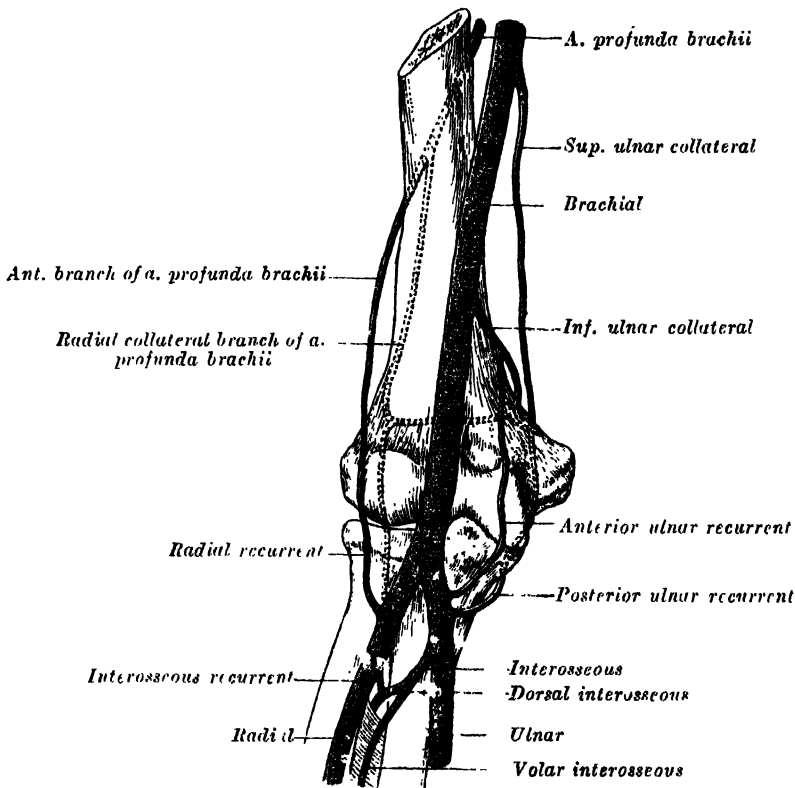
4. The *inferior ulnar collateral artery* (*arteria anastomotica magna*) arises about 5 cm. above the elbow. It passes medialwards upon the *Brachialis* and, piercing the medial intermuscular septum, winds round the back of the humerus between the *Triceps brachii* and the bone, forming, by its junction with the *arteria profunda brachii*, an arch above the olecranon fossa. As the vessel lies on the *Brachialis*, it gives off branches which ascend to join the superior ulnar collateral artery; others descend in front of the medial epicondyle, to anastomose with the anterior ulnar recurrent artery. Behind the medial epicondyle a branch anastomoses with the superior ulnar collateral and posterior ulnar recurrent arteries.

5. The *muscular branches*, three or four in number, are distributed to the *Coracobrachialis*, *Biceps brachii*, and *Brachialis*.

The anastomosis around the elbow-joint (fig. 633).—The vessels engaged in this anastomosis may be conveniently divided into those situated *in front of*, and those

behind the medial and lateral epicondyles of the humerus. The branches anastomosing *in front* of the medial epicondyle are: the anterior branches of the superior and inferior ulnar collateral arteries and the anterior ulnar recurrent artery. Those *behind* the medial epicondyle are: the superior and inferior ulnar collateral arteries and the posterior ulnar recurrent artery. The branches anastomosing *in front* of the lateral epicondyle are: the terminal part of the arteria profunda brachii and the radial recurrent artery. Those *behind* the lateral epicondyle

FIG. 633.—Diagram of the anastomosis around the elbow-joint.



are: the radial collateral branch of the arteria profunda brachii, the inferior ulnar collateral, and interosseous recurrent arteries. There is also an arch of anastomosis above the olecranon, formed by the inferior ulnar collateral artery joining with the interosseous recurrent and the posterior ulnar recurrent arteries (fig. 636).

RADIAL ARTERY (fig. 634)

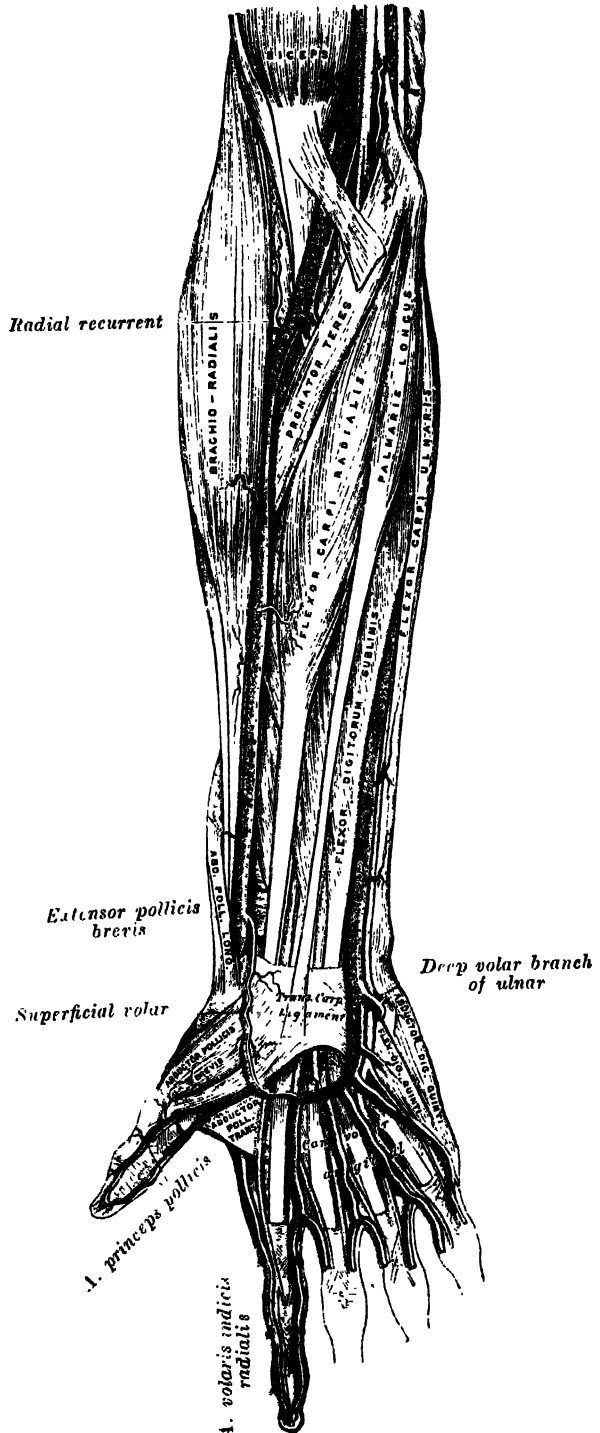
The radial artery, though smaller than the ulnar, appears, from its direction, to be the continuation of the brachial artery. It begins at the bifurcation of the brachial, about 1 cm. below the bend of the elbow, and passes along the radial side of the forearm to the wrist. It then winds backwards, round the lateral side of the carpus, under cover of the tendons of the Abductor pollicis longus and Extensores pollicis brevis and longus to the upper end of the space between the first and second metacarpal bones where it passes forwards between the two heads of the first Interosseus dorsalis, into the palm of the hand; it crosses towards the ulnar side of the palm, and unites with the deep volar branch of the ulnar artery to form the deep volar arch. The radial artery is therefore divisible into three portions, one in the forearm, a second at the back of the wrist, and a third in the hand.

Relations.—(a) *In the forearm*, the radial artery extends from the neck of the radius to the front part of its styloid process, being placed to the medial side of the body of the bone above, and in front of it below. Its upper part is overlapped by the fleshy belly of the Brachioradialis; the rest of the artery is only covered by the skin, the superficial and deep fasciæ. It lies successively upon the tendon of the Biceps brachii, the Supinator, the Pronator teres, the radial origin of the Flexor digitorum sublimis, the Flexor pollicis longus, the Pronator quadratus, and the lower end of the radius. In the upper third of its course it is placed between the Brachioradialis and the Pronator teres; in the lower two-thirds, between the tendons of the Brachioradialis and Flexor carpi radialis. The superficial branch of the radial nerve is close to the lateral side of the artery in the middle third of its course: and some filaments of the lateral antibrachial cutaneous nerve run along the lower part of the artery as it winds round the wrist. The artery is accompanied by a pair of venæ comitantes.

(b) *At the wrist*, the radial artery reaches the back of the carpus by passing between the radial collateral ligament of the wrist and the tendons of the Abductor pollicis longus and Extensor pollicis brevis. It then descends on the navicular and greater multangular bones, and before disappearing between the heads of the first Interosseus dorsalis is crossed by the tendon of the Extensor pollicis longus. In the interval between the two Extensores pollicis it is crossed by the digital rami of the superficial branch of the radial nerve, which go to the thumb and index finger.

(c) *In the hand*, the radial artery passes from the upper end of the first interosseous space, between the heads of the first Interosseus dorsalis, transversely across the palm; it lies at first beneath the oblique part of the

FIG. 634.—Right radial and ulnar arteries.



Adductor pollicis, then runs between the oblique and transverse parts, or through the transverse part, of that muscle, and, at the base of the fifth metacarpal bone, anastomoses with the deep volar branch from the ulnar artery, completing the *deep volar arch* (fig. 635).

Peculiarities.—In about 12 per cent. of cases the origin of the radial artery is higher than usual; it then arises more often from the axillary or upper part of the brachial than from the lower part of the latter vessel. In the forearm it deviates less frequently from its normal position than the ulnar artery. It sometimes lies on the deep fascia instead of beneath it, and on the surface of the *Brachioradialis* instead of under its medial border; in turning round the wrist, it occasionally lies on, instead of beneath, the *extensor tendons* of the thumb.

Applied Anatomy.—The radial artery is much exposed to injury in its lower third, and is frequently wounded; the injury may be followed by a traumatic aneurysm.

Ligature of the radial artery is required in cases of wounds either of its trunk, or of some of its branches, or for aneurysm. In the middle or distal third of the forearm it is easily reached; but in the proximal third, near the elbow, the operation is attended with some difficulty, owing to the greater depth of the vessel, and its being overlapped by the *Brachioradialis*.

To tie the artery in the proximal third of the forearm, an incision 7 or 8 cm. long should be made through the skin, in a line drawn from the centre of the bend of the elbow to the front of the styloid process of the radius, avoiding the branches of the medial antibrachial vein; when the fascia of the arm is divided, and the *Brachioradialis* drawn aside, the artery will be exposed. The *venæ comitantes* should be separated from the vessel and the ligature passed from the radial to the ulnar side.

In the middle third of the forearm the artery may be exposed by making an incision of similar length on the medial border of the *Brachioradialis*. In this situation, the superficial part of the radial nerve lies in close relation with the lateral side of the artery, and should be avoided.

In the distal third, the artery is easily secured by dividing the skin and fascia between the tendons of the *Brachioradialis* and *Flexor carpi radialis*. When operating on the cadaver, students are apt to forget how near to the surface the artery is in this situation.

The branches of the radial artery may be divided into three groups, corresponding with the three regions in which the vessel is situated.

<i>In the forearm.</i>	<i>At the wrist.</i>	<i>In the hand.</i>
Radial recurrent.	Dorsal carpal.	Princeps pollicis.
Muscular.	First dorsal metacarpal.	Volaris indicis radialis.
Volar carpal.		
Superficial volar.		

The **radial recurrent artery** arises immediately below the elbow. It ascends between the branches of the radial nerve, lying on the *Supinator* and then between the *Brachioradialis* and *Brachialis*; it supplies these muscles and the elbow-joint, and anastomoses with the terminal part of the *arteria profunda brachii*.

The **muscular branches** are distributed to the muscles on the radial side of the forearm.

The **volar carpal branch** is a small vessel which arises near the lower border of the *Pronator quadratus*, and, running across the front of the carpus, anastomoses with the volar carpal branch of the ulnar artery. This anastomosis is joined by a branch from the volar interosseous artery, and by recurrent branches from the deep volar arch, thus forming a *volar carpal network* which supplies the articulations of the wrist and carpus.

The **superficial volar branch** arises from the radial artery, just where this vessel is about to wind round the lateral side of the wrist. Running forwards, it passes through, occasionally over, the muscles of the ball of the thumb, which it supplies, and sometimes anastomoses with the terminal portion of the ulnar artery completing the superficial volar arch. This vessel varies considerably in size: usually it is very small, and ends in the muscles of the thumb; sometimes it is as large as the continuation of the radial.

The **dorsal carpal branch** is a small vessel which arises beneath the *Extensor tendons* of the thumb; crossing the back of the carpus transversely towards the medial border of the hand, it anastomoses with the dorsal carpal branch of the ulnar artery, and with the volar and dorsal interosseous arteries to form a *dorsal*

carpal network. From this network are given off three slender *dorsal metacarpal arteries*, which descend on the second, third, and fourth Interossei dorsales and bifurcate into dorsal digital branches for the supply of the adjacent sides of the middle, ring, and little fingers respectively; they communicate with the proper volar digital branches of the superficial volar arch; near their origins they anastomose with the deep volar arch by the *superior perforating arteries*, and near their points of bifurcation with the common volar digital vessels of the superficial volar arch by the *inferior perforating arteries*.

The **first dorsal metacarpal artery** arises just before the radial artery passes between the two heads of the first Interosseus dorsalis, and divides almost immediately into two branches which supply the adjacent sides of the thumb and index finger; the radial side of the thumb receives a branch directly from the radial artery.

The **arteria princeps pollicis** arises from the radial artery just as it turns medially towards the deep part of the hand; it descends between the first Interosseus dorsalis and the oblique part of the Adductor pollicis, along the medial side of the metacarpal bone of the thumb to the base of the first phalanx, where it lies beneath the tendon of the Flexor pollicis longus and divides into two branches. These make their appearance between the medial and lateral insertions of the oblique part of the Adductor pollicis, and run along the sides of the thumb, forming on the volar surface of the last phalanx an arch, from which branches are distributed to the integument and subcutaneous tissue of the thumb.

The **arteria volaris indicis radialis**, frequently a branch of the proximal part of the arteria princeps pollicis, descends between the first Interosseus dorsalis and the transverse part of the Adductor pollicis, and runs along the lateral side of the index finger to its extremity, where it anastomoses with the proper digital artery supplying the medial side of the finger. At the lower border of the transverse part of the Adductor pollicis this vessel anastomoses with the arteria princeps pollicis, and gives a communicating branch to the superficial volar arch.

The arteria princeps pollicis and arteria volaris indicis radialis may spring from a common trunk termed the *first volar metacarpal artery*.

The **deep volar arch** (deep palmar arch) (fig. 635) is formed by the anastomosis of the terminal part of the radial artery with the deep volar branch of the ulnar artery. It lies upon the proximal ends of the metacarpal bones and on the Interossei, and is covered by the oblique part of the Adductor pollicis, the flexor tendons of the fingers, and the Lumbricales. Alongside it, but running in the opposite direction—that is to say, towards the lateral side of the hand—is the deep branch of the ulnar nerve.

The branches of the deep volar arch are: volar, metacarpal, perforating, and recurrent.

Volar metacarpal arteries, three in number, arise from the convexity of the deep volar arch; they run distally upon the Interossei of the second, third, and fourth spaces, and anastomose at the clefts of the fingers with the common digital branches of the superficial volar arch.

Perforating branches, three in number, pass backwards from the deep volar arch, through the second, third, and fourth interosseous spaces and between the heads of the corresponding Interossei dorsales, to anastomose with the dorsal metacarpal arteries.

Recurrent branches arise from the concavity of the deep volar arch; they ascend in front of the wrist, supply the intercarpal articulations and end in the volar carpal network.

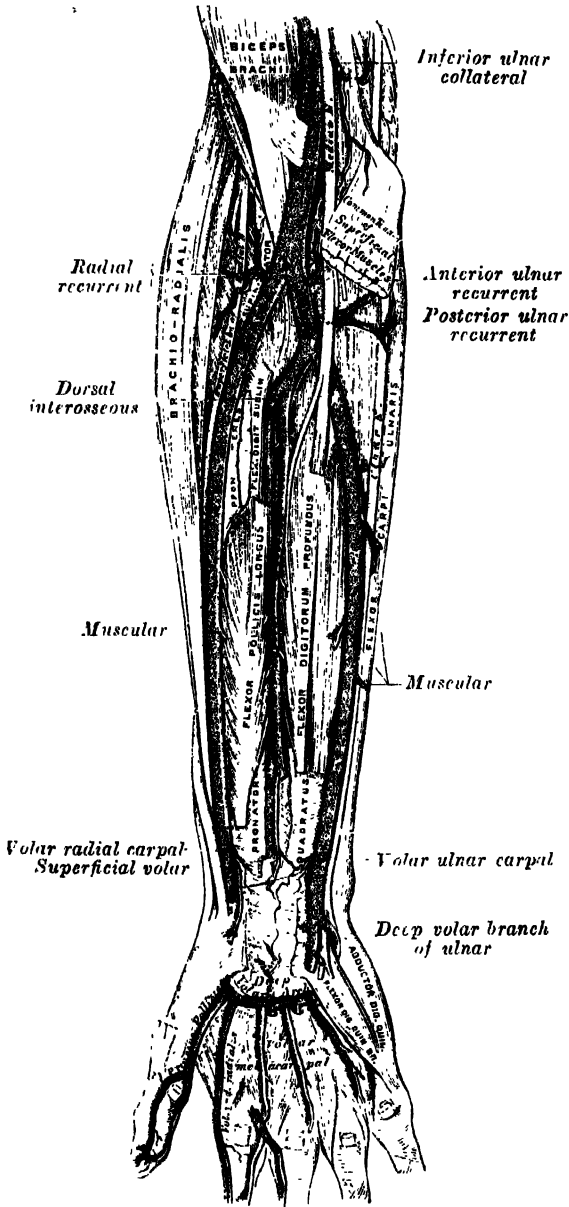
ULNAR ARTERY (fig. 635)

The **ulnar artery**, the larger of the two terminal branches of the brachial artery, begins about 1 cm. below the bend of the elbow, and, passing obliquely downwards, reaches the ulnar side of the forearm at a point about midway between the elbow and the wrist. It then runs along the ulnar border to the wrist, crosses the transverse carpal ligament on the radial side of the pisiform bone and immediately beyond this bone divides into two branches, which enter into the formation of the superficial and deep volar arches.

Relations.—(a) *In the forearm.*—The *upper half* of the vessel is deeply seated, being covered by the Pronator teres, Flexor carpi radialis, Palmaris longus, and Flexor digitorum sublimis; it lies upon the Brachialis and Flexor digitorum

profundus. The median nerve is in relation with the medial side of the artery for about 2.5 cm. and then crosses the it by the ulnar head of the Pronator teres. The *lower half* lies upon the

FIG. 635.—Right radial and ulnar arteries.
Deep view.



Flexor digitorum profundus; it is covered by the skin, superficial and deep fasciæ, and is placed between the Flexor carpi ulnaris and Flexor digitorum sublimis.

It is accompanied by two venæ comitantes, and is overlapped in its middle third by the Flexor carpi ulnaris; the ulnar nerve lies on the medial side of the lower two-thirds of the artery, and the palmar cutaneous branch of the nerve descends on the lower part of the vessel to the palm of the hand.

(b) *At the wrist* (fig. 634) the ulnar artery is covered by the integument and the volar carpal ligament, and lies upon the transverse carpal ligament. On its medial side is the pisiform bone, and, somewhat behind the artery, the ulnar nerve.

Peculiarities.—The ulnar artery varies in its origin in about 8 per cent. of cases; it frequently arises above the elbow, the brachial being more often the source of origin than the axillary. When its origin is normal, the course of the vessel is rarely changed. When it arises high up, it is almost invariably superficial to the flexor muscles in the forearm, lying commonly beneath the fascia, more rarely between the fascia and skin; the brachial artery then gives off the common interosseous artery, and the latter, the anterior and posterior ulnar recurrent arteries. Occasionally it is subcutaneous in the upper part of the forearm, and subaponeurotic in the lower part.

Applied Anatomy.—Ligature of the ulnar artery is required in cases of wound of the artery, or

of its branches, or in consequence of aneurysm. Ligature of the artery in the upper half of the forearm is attended with some difficulty as this part of the vessel is deeply seated beneath the superficial flexor muscles. An incision is to be made in the course of a line drawn from the front of the medial epicondyle of the humerus to the lateral side of the pisiform bone, so that the centre of the incision is three fingers' breadths below the medial epicondyle. The skin and superficial fascia having been divided, and the deep fascia exposed, the white line which separates the Flexor carpi ulnaris from the other flexor muscles is to be sought for, and the fascia incised in this line. The Flexor carpi ulnaris is now to be carefully separated from the other muscles, when the ulnar nerve will be exposed lying on the Flexor digitorum profundus, and must be drawn aside. The artery, accompanied by its venæ comitantes, lies to the lateral side of the nerve. In the middle

and lower thirds of the forearm, the artery may be easily secured by making an incision on the radial side of the tendon of the Flexor carpi ulnaris: when the deep fascia is divided, and the tendon separated from the Flexor digitorum sublimis, the vessel will be exposed, accompanied by its venæ comitantes, the ulnar nerve lying on its medial side.

The branches of the ulnar artery may be arranged in the following groups:

<i>In the forearm</i>	Anterior recurrent.	<i>At the wrist</i>	Volar carpal.
	Posterior recurrent.		Dorsal carpal.
	Common interosseous.	<i>In the hand</i>	Deep volar.
	Muscular.		Superficial volar arch.

The **anterior ulnar recurrent artery** arises immediately below the elbow-joint, runs upwards between the Brachialis and Pronator teres, supplies twigs to those muscles, and, in front of the medial epicondyle, anastomoses with the superior and inferior ulnar collateral arteries.

The **posterior ulnar recurrent artery** is much larger, and arises somewhat lower than the preceding artery. It passes backwards and medialwards on the Flexor digitorum profundus, behind the Flexor digitorum sublimis, and ascends behind the medial epicondyle of the humerus. In the interval between this process and the olecranon, it lies beneath the Flexor carpi ulnaris, and ascends between the heads of this muscle, in relation with the ulnar nerve; it supplies the neighbouring muscles and the elbow-joint, and anastomoses with the superior and inferior ulnar collateral and the interosseous recurrent arteries (fig. 636).

The **common interosseous artery** (fig. 635), about 1 cm. in length, arises immediately below the tuberosity of the radius, and, passing backwards to the upper border of the antibrachial interosseous membrane, divides into two branches, the *volar* and *dorsal interosseous arteries*.

The **volar interosseous artery** (fig. 635) descends on the volar surface of the antibrachial interosseous membrane, accompanied by the volar interosseous branch of the median nerve, and overlapped by the contiguous margins of the Flexor digitorum profundus and Flexor pollicis longus; it gives off *muscular* branches, and the *nutrient* arteries of the radius and ulna. At the upper border of the Pronator quadratus it pierces the membrane and reaches the back of the forearm, where it anastomoses with the dorsal interosseous artery and descends on the back of the wrist in the compartment of the dorsal carpal ligament containing the tendons of the Extensor digitorum communis and Extensor indicis proprius, and joins the dorsal carpal network. The volar interosseous artery gives off a slender branch, the *arteria mediana*, which accompanies the median nerve, and sends offsets to its substance; this artery is sometimes much enlarged, and runs with the median nerve into the palm of the hand. Before the volar interosseous artery pierces the antibrachial interosseous membrane, it sends a branch downwards behind the Pronator quadratus to join the volar carpal network.

The **dorsal interosseous artery** (fig. 636), usually smaller than the volar interosseous artery, passes backwards between the oblique cord and the upper border of the antibrachial interosseous membrane. It appears on the back of the forearm between the contiguous borders of the Supinator and the Abductor pollicis longus, and descends between the superficial and deep layers of muscles, to both of which it distributes branches. As it lies upon the Abductor pollicis longus and the Extensor pollicis brevis, it is accompanied by the deep branch of the radial nerve. At the lower part of the forearm it anastomoses with the termination of the volar interosseous artery, and with the dorsal carpal network. It gives off, near its origin, the *interosseous recurrent artery*, which ascends to the interval between the lateral epicondyle and olecranon, on or through the fibres of the Supinator, but beneath the Anconæus, and anastomoses with the radial collateral branch of the arteria profunda brachii, the posterior ulnar recurrent, and the inferior ulnar collateral arteries.

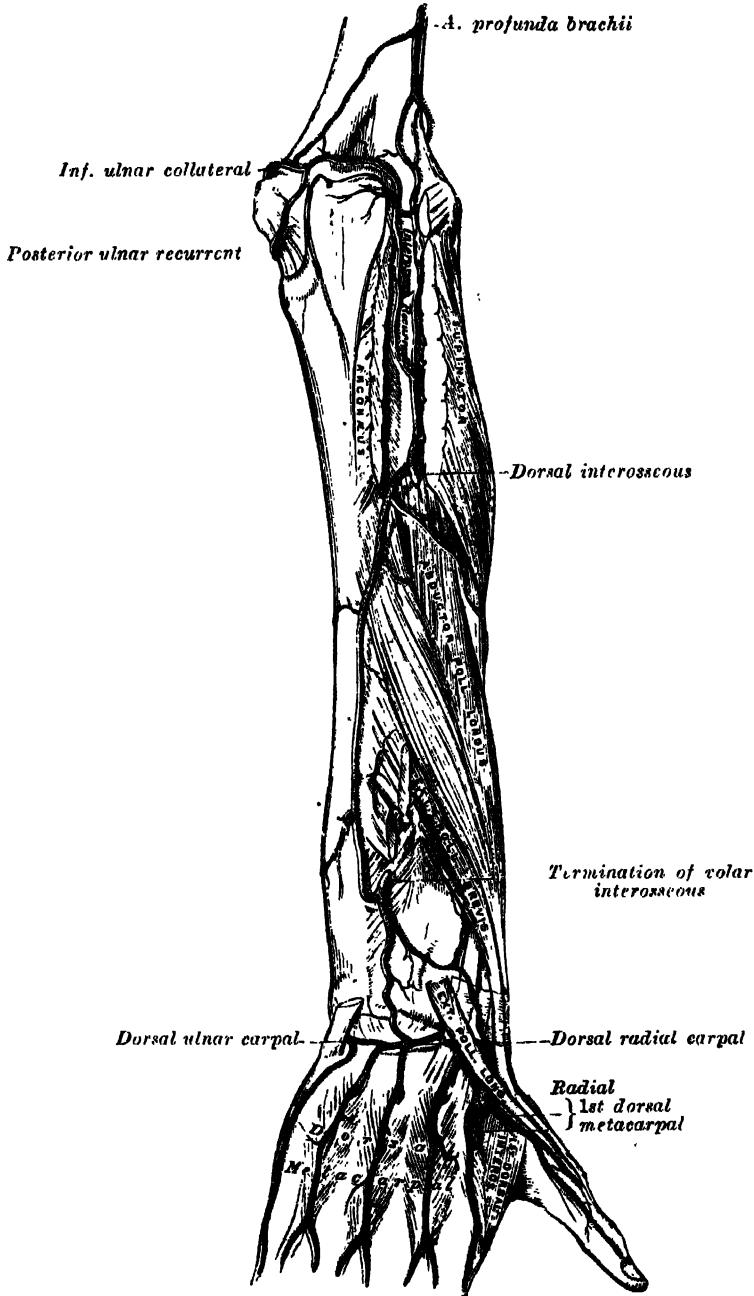
The **muscular branches** are distributed to the muscles along the ulnar side of the forearm.

The **volar carpal branch** is a small vessel which crosses the front of the carpus behind the tendons of the Flexor digitorum profundus; it anastomoses with the volar carpal branch of the radial artery, and assists in forming the volar carpal network.

The **dorsal carpal branch** arises immediately above the pisiform bone, and winds backwards beneath the tendon of the Flexor carpi ulnaris; it passes across

the dorsal surface of the carpus under cover of the extensor tendons, anastomoses with the dorsal carpal branch of the radial artery, and assists in forming the dorsal carpal network. Close to its origin it gives off a small branch, which runs along

FIG. 636.—Arteries of the back of the right forearm and hand.



the ulnar side of the fifth metacarpal bone, and supplies the ulnar side of the dorsal surface of the little finger.

The **deep volar branch** (fig. 635) passes between the Abductor digiti quinti and Flexor digiti quinti brevis and through the origin of the Opponens digiti quinti; it anastomoses with the radial artery, and completes the deep volar arch.

The **superficial volar arch** (superficial palmar arch) (fig. 634) is formed mainly by the ulnar artery, and is usually completed by a branch from the *arteria volaris indicis radialis*, but sometimes by the superficial volar artery or by a branch from the *arteria princeps pollicis* of the radial artery. The arch passes across the palm, describing a curve, with its convexity downwards.

Relations.—It is covered by the skin, the *Palmaris brevis*, and the palmar aponeurosis. It lies upon the transverse carpal ligament, the *Flexor digiti quinti brevis* and *Opponens digiti quinti*, the tendons of the *Flexor digitorum sublimis*, the *Lumbricales*, and the divisions of the median and ulnar nerves.

Three **common volar digital arteries** (fig. 634) arise from the convexity of the superficial volar arch and proceed downwards on the second, third, and fourth *Lumbricales*. Each is joined by the corresponding volar metacarpal artery, and then divides into a pair of *proper volar digital arteries* which run along the contiguous sides of the index, middle, ring, and little fingers, behind the corresponding digital nerves; they anastomose freely in the subcutaneous tissue of the finger tips and by smaller branches near the interphalangeal joints. Each gives off a couple of dorsal branches which anastomose with the dorsal digital arteries, and supply the soft parts on the back of the second and third phalanges, including the matrix of the finger-nail. The proper volar digital artery for the medial side of the little finger springs from the ulnar artery under cover of the *Palmaris brevis*.

Applied Anatomy.—Wounds of the volar arches are always difficult to deal with. When the superficial arch is involved it is generally possible (enlarging the wound when necessary) to secure the vessel and tie it on both sides of the bleeding point; or in cases where it is found impossible to encircle the vessel with a ligature, a pair of Wells's artery clips may be applied and left on for twenty-four or forty-eight hours. Failing this, the wound may be plugged with gauze and an outside dressing carefully bandaged on. The plug should be allowed to remain untouched for three or four days. It is useless in these cases to ligature one of the arteries of the forearm alone, and indeed simultaneous ligature of both radial and ulnar arteries above the wrist is often unsuccessful, on account of the anastomosis carried on by the carpal arches. Therefore, upon the failure of pressure to arrest hæmorrhage, it is expedient to apply a ligature to the brachial artery.

When an incision for deep-seated suppuration in the tendon-sheath is required, the situation of the superficial arch must always be borne in mind, and the incisions placed either above or below it. The position of the common digital branches of the artery must also be remembered, and the incisions made in front of the heads of the metacarpal bones and not between them.

ARTERIES OF THE TRUNK

DESCENDING AORTA

The **descending aorta** is divided into two portions, the *thoracic* and *abdominal*, in correspondence with the two great cavities in which it is situated.

THORACIC AORTA (fig. 637)

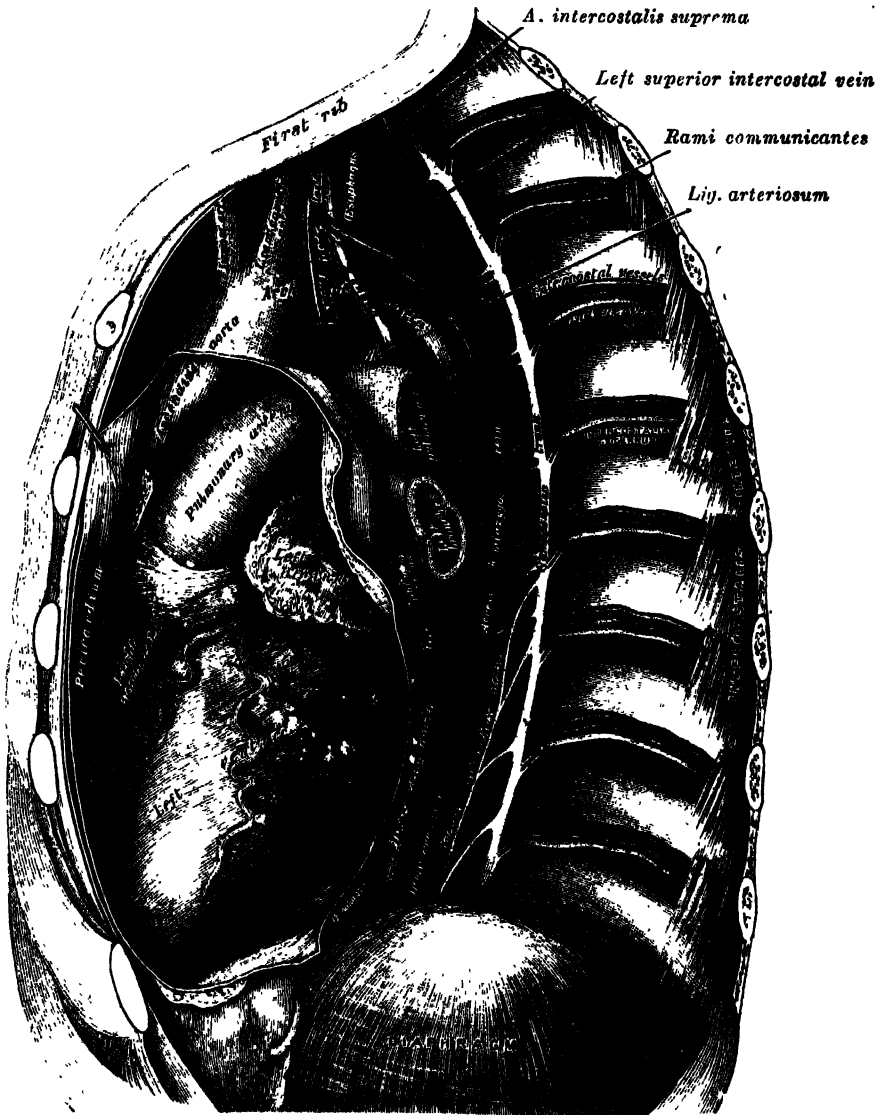
The **thoracic aorta** is contained in the posterior mediastinal cavity. It begins at the lower border of the fourth thoracic vertebra where it is continuous with the aortic arch, and ends in front of the lower border of the twelfth thoracic vertebra at the aortic hiatus in the Diaphragm. At its commencement, it is situated on the left of the vertebral column; it approaches the median line as it descends, and at its termination lies in front of the column.

Relations.—It is in relation, *anteriorly*, from above downwards, with the root of the left lung, the pericardium, the œsophagus, and the Diaphragm; *posteriorly*, with the vertebral column, the hemiazygos and accessory hemiazygos veins; on the *right side*, with the azygos vein and thoracic duct; on the *left side*, with the left pleura and lung. The œsophagus, with its accompanying plexus of nerves lies on the right side of the aorta above; but at the lower part of the thorax it is placed in front of the aorta, and, close to the Diaphragm, is situated on its left side.

Peculiarities.—The lumen of the aorta is occasionally found to be partly or completely obliterated, either at the aortic isthmus, or close to the point where the ductus arteriosus

opens into it. This condition is known as *coarctation of the aorta*. It may be either congenital or acquired. In the former case the infant usually dies at or soon after birth. In the latter case it is apparently due to an abnormal extension of the peculiar tissue of the ductus into the aortic wall, giving rise to a simultaneous stenosis of both vessels as it contracts after birth. This form of coarctation is compatible with many years of normal life, and leads to the establishment of an extensive collateral circulation to carry blood to

FIG. 637.—The heart and thoracic aorta, viewed from the left side.



the aorta immediately below the stenosis by means of the following vessels—Firstly, the internal mammary, anastomosing with the intercostal arteries, with the inferior phrenic of the abdominal aorta by means of the musculophrenic and pericardiophrenic, and largely with the inferior epigastric. Secondly, the costocervical trunk, anastomosing anteriorly by means of a large branch with the first aortic intercostal, and posteriorly with the posterior branch of the same artery. Thirdly, the inferior thyreoid, by means of a branch about the size of an ordinary radial, forming a communication with the first aortic intercostal. Fourthly, the transverse cervical, by means of very large communications with the posterior branches of the intercostals. Fifthly, the branches (of the subclavian and axillary) going to the side of the chest enlarge, and anastomose freely with the lateral branches of the intercostals. In a second case Wood describes the anastomoses

in a somewhat similar manner, adding the remark, that 'the blood which was brought into the aorta through the anastomoses of the intercostal arteries appeared to be expended principally in supplying the abdomen and pelvis; while the supply to the lower extremities had passed through the internal mammary and epigastrics.'

Applied Anatomy.—The effects likely to be produced by aneurysm of the thoracic aorta, a disease of common occurrence, must now be considered. When the great depth of the vessel from the surface, and the number of important structures which surround it, are remembered, it may easily be conceived what a variety of obscure symptoms are likely to arise from disease of this vessel, and how they may be mistaken for those of other affections. Aneurysm of the thoracic aorta most usually extends backwards, along the left side of the vertebral column, producing absorption of the bodies of the vertebrae, with curvature of the column; while the irritation or pressure on the medulla spinalis will give rise to pain, either in the chest, back, or loins, with radiating pain in the left upper intercostal spaces, from pressure on the intercostal nerves; at the same time the aneurysm may project backwards on either side of the vertebral column, beneath the skin, as a pulsating swelling, simulating abscess connected with diseased bone; or it may displace the œsophagus, or compress the lung on one or the other side. If the aneurysm extend forward, it may press upon and displace the heart, giving rise to palpitation and other symptoms of disease of that organ; it may displace or compress the œsophagus, causing pain and difficulty of swallowing; and ultimately even open into it by ulceration, producing fatal hæmorrhage. If the aneurysm extend to the right side, it may press upon the thoracic duct; or it may burst into the pleural cavity, or into the trachea or lung; and, lastly, it may open into the posterior mediastinal cavity. Pressure on one of the bronchi, usually the left, will cause cough, and in time set up bronchiectasis; pressure on the left pulmonary plexus has been said to give rise to asthmatic attacks. Of late years, the diagnosis of thoracic aneurysm has been much facilitated by the employment of the x-rays, by means of which the outline of the sac may be demonstrated.

BRANCHES OF THE THORACIC AORTA

Visceral	{	Pericardial.	Parietal	{	Mediastinal.
		Bronchial.			Superior phrenic.
		(Esophageal.			Intercostal.
					Subcostal.

The **pericardial branches** consist of a few small vessels which are distributed to the posterior surface of the pericardium.

The **bronchial arteries** vary in number, size, and origin. There is as a rule one *right bronchial artery*, which arises from the first aortic intercostal artery, or from the upper left bronchial artery. The *left bronchial arteries* are usually two in number and arise from the thoracic aorta. The upper left bronchial artery arises opposite the fifth thoracic vertebra, the lower just below the level of the left bronchus. Each vessel runs on the posterior surface of its bronchus, dividing and subdividing along the bronchial tubes, supplying them, the areolar tissue of the lungs, the bronchial lymph-glands, and the œsophagus.

The **œsophageal arteries**, four or five in number, arise from the front of the aorta, and pass obliquely downwards to the œsophagus; on this they form a vascular chain which anastomoses with the œsophageal branches of the inferior thyroid arteries above, and with ascending branches from the left inferior phrenic and left gastric arteries below.

The **mediastinal branches** are numerous small vessels which supply the lymph-glands and loose areolar tissue in the posterior mediastinal cavity.

The **superior phrenic branches** are small, and arise from the lower part of the thoracic aorta; they are distributed to the posterior part of the upper surface of the Diaphragm, and anastomose with the musculophrenic and pericardiophrenic arteries.

Intercostal arteries.—There are usually nine pairs of aortic intercostal arteries. They arise from the back of the aorta, and are distributed to the lower nine intercostal spaces, the first and second spaces being supplied by the *arteria intercostalis suprema*, a branch of the costocervical trunk of the subclavian artery. The *right aortic intercostal arteries* are longer than the left, on account of the position of the aorta on the left side of the vertebral column; they cross the bodies of the vertebrae behind the œsophagus, thoracic duct, and vena azygos, and are covered by the right lung and pleura. The *left aortic intercostal arteries* run backwards on the sides of the vertebrae and are covered by the left lung and pleura; the upper two vessels are crossed by the left superior intercostal vein, the lower vessels by the

hemiazygos and accessory hemiazygos veins. The further course of the intercostal arteries is practically the same on both sides. Opposite the heads of the ribs the sympathetic trunk passes downwards in front of them, and the splanchnic nerves also descend in front of the lower arteries. Each artery then divides into an anterior and a posterior ramus.

The *anterior ramus* crosses the corresponding intercostal space obliquely towards the angle of the upper rib, and thence is continued forward in the costal groove. It is placed at first between the pleura and the posterior intercostal membrane; it then pierces this membrane, and lies between it and the *Intercostalis externus* as far as the angle of the rib; from this onward it runs between the *Intercostales externus* and *internus*, and anastomoses in front with the intercostal branch of the internal mammary or musculophrenic artery. Each artery is accompanied by a vein and a nerve, the former being above and the latter below the artery, except in the upper spaces, where the nerve is at first above the artery. The first aortic intercostal artery anastomoses with the *arteria intercostalis suprema*, and may form the chief supply of the second intercostal space. The lower two intercostal arteries are continued anteriorly from the intercostal spaces into the abdominal wall, and anastomose with the subcostal, superior epigastric, and lumbar arteries.

Each anterior ramus gives off the following branches:

Collateral intercostal.
Muscular.

Lateral cutaneous.
Mammary.

The *collateral intercostal branch* comes off the anterior ramus of the intercostal artery near the angle of the rib, and descends to the upper border of the rib below, along which it courses to anastomose with an intercostal branch of the internal mammary or musculophrenic artery.

Muscular branches are given to the *Intercostales* and *Pectorales*, and to the *Serratus anterior*; they anastomose with the highest and lateral thoracic branches of the axillary artery.

The *lateral cutaneous branches* accompany the lateral cutaneous branches of the thoracic nerves.

Mammary branches are given off by the vessels in the third, fourth, and fifth spaces; they increase considerably in size during the period of lactation.

Each *posterior ramus* runs backwards through a space which is bounded above and below by the necks of the ribs, medially by the body of a vertebra, and laterally by an anterior costotransverse ligament. It gives off a *spinal branch* which enters the vertebral canal through the intervertebral foramen and is distributed to the *medulla spinalis* and its membranes and the *vertebræ*, anastomosing with the spinal arteries above and below and with the artery of the opposite side. It then courses over the transverse process with the posterior division of the thoracic nerve, supplies branches to the muscles of the back, and a cutaneous branch which accompanies the cutaneous branch of the posterior division of the corresponding nerve.

Applied Anatomy.—The position of the anterior rami of the intercostal vessels should be borne in mind in performing the operation of *paracentesis thoracis*. The puncture should never be made nearer the middle line posteriorly than the angle of the rib, as the artery crosses the space medially to this point. In the lateral portion of the chest, where the puncture is usually made, the artery lies at the upper part of the intercostal space, and therefore the puncture should be made just above the upper border of the rib forming the lower boundary of the space.

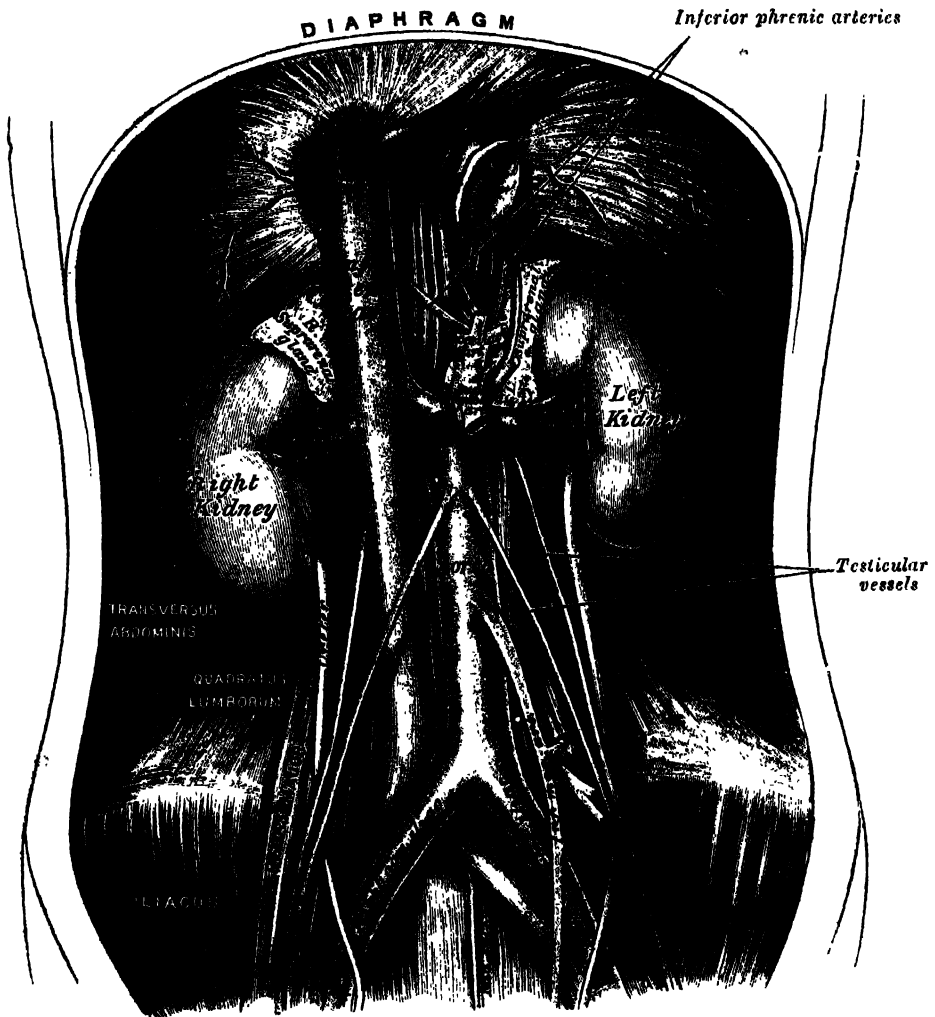
The *subcostal arteries*, so named because they lie below the last ribs, are in series with the intercostal arteries. Each passes along the lower border of the twelfth rib behind the kidney and in front of the *Quadratus lumborum* muscle, and is accompanied by the twelfth thoracic nerve. It then pierces the posterior aponeurosis of the *Transversus abdominis*, and, passing forward between this muscle and the *Obliquus internus*, anastomoses with the superior epigastric, lower intercostal, and lumbar arteries. Each subcostal artery gives off a posterior branch which has a distribution similar to the posterior ramus of an intercostal artery.

A small *aberrant artery* is sometimes found arising from the right side of the thoracic aorta near the origin of the right bronchial. It passes upwards and to the right behind the trachea and the oesophagus, and may anastomose with the right *arteria intercostalis suprema*. It represents the remains of the right dorsal aorta (p. 121), and in a small proportion of cases is enlarged to form the first part of the right subclavian artery.

ABDOMINAL AORTA (fig. 638)

The abdominal aorta begins at the aortic hiatus of the Diaphragm, in front of the lower border of the body of the last thoracic vertebra, and, descending in front of the vertebral column, ends on the body of the fourth lumbar vertebra, a little to the left of the middle line, by dividing into the two common iliac arteries. It diminishes rapidly in size, in consequence of the large branches which arise from it.

FIG. 638.—The abdominal aorta and its branches.



Relations.—The abdominal aorta is covered, *anteriorly*, by the omental bursa and stomach, behind which are the branches of the coeliac artery and the coeliac plexus of nerves; below these, by the lienal vein, the pancreas, the left renal vein, the inferior part of the duodenum, the root of the mesentery, and aortic plexus of nerves. *Posteriorly*, it is separated from the lumbar vertebrae and intervertebral fibrocartilages by the anterior longitudinal ligament and left lumbar veins. On the *right side* it is in relation above with the cisterna chyli, thoracic duct, azygos vein, and the right crus of the Diaphragm—the last separating it from the upper part of the inferior vena cava, and from the right coeliac ganglion; the inferior vena cava is in contact with the aorta below the level of the second lumbar vertebra.

On the *left side* are the left crus of the Diaphragm, the left celiac ganglion, the ascending part of the duodenum, some coils of the small intestine, the left sympathetic trunk, inferior mesenteric and left testicular vessels, and the left ureter.

Applied Anatomy.—The abdominal aorta may be the seat of an aneurysm either at its upper part, close to and often involving the celiac artery, or at its lower part, near the bifurcation. Occasionally aneurysms are met with on some of the branches of the aorta, e.g., the mesenteric or lienal arteries.

When an aneurysm is connected with the posterior part of the abdominal aorta, it usually produces absorption of the bodies of the vertebræ. Pain is invariably present, and is usually of two kinds—a fixed and constant pain in the back, caused by the tumour pressing on or displacing the branches of the celiac plexus and splanchnic nerves; and a sharp lancinating pain, radiating along those branches of the lumbar nerves which are pressed on by the tumour; hence the pain in the loins, the testes, the hypogastrium, and in the lower limb (generally of the left side). This form of aneurysm usually bursts into or behind the peritoneal cavity.

When an aneurysm is connected with the front of the aorta near the celiac artery, it forms a pulsating tumour in the left hypochondriac or epigastric regions, usually attended with symptoms of disturbance of the digestive tube, as sickness, dyspepsia, or constipation, and accompanied by pain, which is constant, but nearly always fixed, in the loins, epigastrium, or some part of the abdomen; the radiating pain being rare, as the lumbar nerves are seldom implicated. This form of aneurysm may burst into the peritoneal cavity, behind the peritoneum, between the layers of the mesentery, or, more rarely, into the duodenum; it rarely extends backwards so as to affect the vertebral column.

Occlusion of the abdominal aorta by thrombosis or embolism is rare, but produces very severe symptoms when it does occur. The patient complains of intense pain in the legs; pallor of the legs, followed by coldness, lividity, paresis, paralysis, and finally gangrene are likely to succeed, death usually supervening within a fortnight.

The abdominal aorta has been tied in several cases, and although none of the patients permanently recovered, still, as one case lived forty-eight days, the possibility of the re-establishment of the circulation may be considered to be proved.

Collateral Circulation.—The collateral circulation would be carried on by the anastomoses between the internal mammary and the inferior epigastric arteries; by the free communication between the superior and inferior mesenteric arteries, if the ligature were placed between these vessels; or by the anastomosis between the inferior mesenteric and the internal pudendal arteries, when (as is more common) the point of ligature is below the origin of the inferior mesenteric artery; and possibly by the anastomoses of the lumbar arteries with the branches of the hypogastric artery.

BRANCHES OF THE ABDOMINAL AORTA

The branches of the abdominal aorta may be divided into three sets: visceral, parietal, and terminal.

Visceral branches.

Celiac.
Superior mesenteric.
Inferior mesenteric.
Middle suprarenal.
Renal.
• Testicular (in the male).
• Ovarian (in the female).

Parietal branches.

Inferior phrenic.
Lumbar.
Middle sacral.

Terminal branches.

Common iliac.

Of the visceral branches, the celiac artery and the superior and inferior mesenteric arteries are unpaired; the suprarenal, renal, testicular, and ovarian arteries are paired. Of the parietal branches, the middle sacral artery is unpaired; the inferior phrenic and lumbar arteries are paired. The terminal branches are paired.

CELIAC ARTERY (figs. 639, 640)

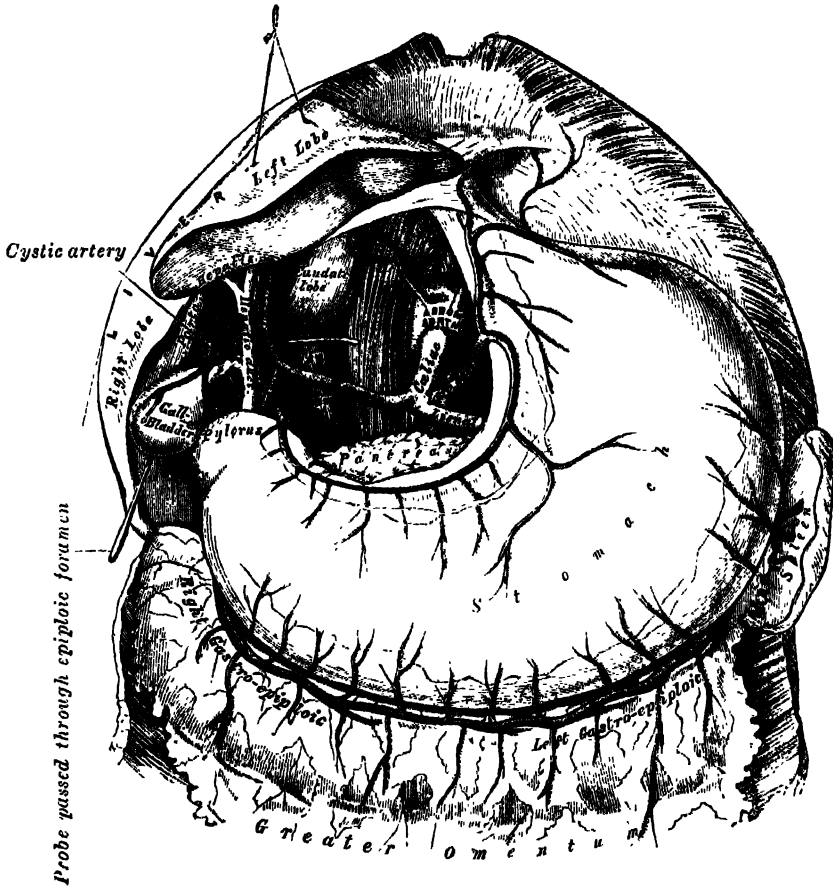
The celiac artery is a thick trunk, about 1.25 cm. long, which arises from the front of the aorta, just below the aortic hiatus of the Diaphragm, it passes nearly horizontally forwards, and divides into three large branches, (1) *left gastric*, (2) *hepatic*, and (3) *lienal* or *splenic*; it occasionally gives off one of the inferior phrenic arteries.

Relations.—The celiac artery is covered by the omental bursa and surrounded by the celiac plexus of nerves. On its *right side* are the right celiac

ganglion and the caudate process of the liver, on its *left side* the left cœliac ganglion and the cardiac end of the stomach. *Below* it are the upper border of the pancreas and the lienal vein.

1. The **left gastric artery** (coronary artery), the smallest branch of the cœliac artery, passes upwards and to the left, behind the omental bursa, to the cardiac orifice of the stomach. Here it gives off branches which ascend on the œsophagus, and anastomose with the aortic œsophageal arteries; others supply the cardiac part of the stomach, and anastomose with branches of the lienal artery. The artery then runs from left to right, along the lesser curvature

FIG. 639.—The cœliac artery and its branches; the liver has been raised, and the lesser omentum and anterior layer of the greater omentum removed.



of the stomach to the pylorus, between the layers of the lesser omentum; it gives branches to both surfaces of the stomach and anastomoses with the right gastric artery.

2. The **hepatic artery** is intermediate in size between the left gastric and lienal. It is first directed forwards and to the right, to the upper margin of the superior part of the duodenum, forming the lower boundary of the epiploic foramen (foramen of Winslow). It then crosses the portal vein anteriorly, and ascends between the layers of the lesser omentum, and in front of the epiploic foramen, to the porta hepatis, where it divides into a right and a left branch, which supply the corresponding lobes of the liver, accompanying the ramifications of the portal vein and hepatic ducts. The hepatic artery, in its course along the right border of the lesser omentum, is in relation with the common bile-duct and portal vein, the duct lying to the right of the artery, and the vein behind. The distribution of the hepatic artery is described with the anatomy of the liver, in the section on Splanchnology.

Its branches are :

Right gastric.

Gastroduodenal { Right gastro-epiploic.
Superior pancreaticoduodenal.

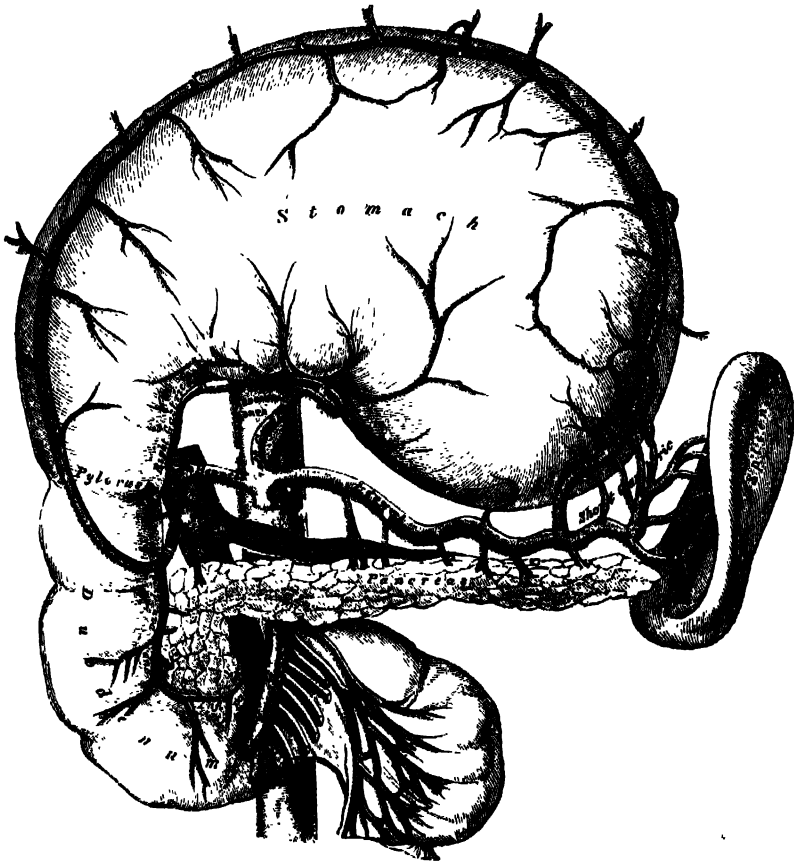
Cystic.

The **right gastric artery** (pyloric artery) arises from the hepatic, above the pylorus, descends to the pyloric end of the stomach, and passes from right to left along its lesser curvature, supplying it with branches, and anastomosing with the left gastric artery.

The **gastroduodenal artery** (fig. 640) is a short but large branch, which descends, near the pylorus, between the superior part of the duodenum and the neck of the

FIG. 640.—The coeliac artery and its branches; the stomach has been raised and the peritoneum removed.

Branches to greater omentum



pancreas, and divides at the lower border of the duodenum into two branches, the *right gastro-epiploic* and the *superior pancreaticoduodenal* arteries. Previous to its division it gives off two or three small branches to the pyloric end of the stomach and to the pancreas.

The **right gastro-epiploic artery** runs from right to left along the greater curvature of the stomach, between the layers of the greater omentum, anastomosing with the left gastro-epiploic branch of the lienal artery. Except at the pylorus, where it is in contact with the stomach, it lies about a finger's breadth from the greater curvature. This vessel gives off numerous branches, some of which ascend to supply both surfaces of the stomach, while others descend in the greater omentum and anastomose with branches of the middle colic artery.

The **superior pancreaticoduodenal artery** descends between the duodenum and the head of the pancreas. It supplies both these organs, and anastomoses with the inferior pancreaticoduodenal branch of the superior mesenteric artery, and with the pancreatic branches of the lienal artery.

The **cystic artery** (fig. 639), usually a branch of the right hepatic artery, passes downwards and forwards along the neck of the gall-bladder, and divides into two branches, one of which ramifies on the free surface, the other on the attached surface of the gall-bladder.

3. The **lienal or splenic artery**, the largest branch of the coeliac artery, is remarkable for the tortuosity of its course. Accompanied by the lienal vein which lies below it, it passes horizontally to the left, behind the stomach and the omental bursa of the peritoneum, and along the upper border of the pancreas; it then crosses in front of the upper part of the left kidney, and, on arriving near the spleen, divides into branches; some of these enter the hilum of the spleen between the two layers of the phrenicocolical ligament; some are given to the pancreas, while others pass to the greater curvature of the stomach between the layers of the gastrosplenic ligament. Its branches are:

Pancreatic.

Short gastric.

Left gastro-epiploic.

The **pancreatic branches** are numerous small vessels supplying the body and tail of the pancreas; they are derived from the lienal artery as it runs behind the upper border of the pancreas. One branch, larger than the rest, is sometimes given off near the tail of the pancreas; it runs from left to right near the posterior surface of the gland, following the course of the pancreatic duct, and is called the *arteria pancreatica magna*. These vessels anastomose with the pancreatic branches of the superior and inferior pancreaticoduodenal arteries.

The **short gastric arteries** (*vasa brevia*) consist of from five to seven small branches which arise from the end of the lienal artery, and from its terminal divisions. They pass from left to right, between the layers of the gastrosplenic ligament, and are distributed to the greater curvature of the stomach, anastomosing with branches of the left gastric and left gastro-epiploic arteries.

The **left gastro-epiploic artery**, the largest branch of the lienal, runs from left to right about a finger's breadth or more from the greater curvature of the stomach, between the layers of the greater omentum, and anastomoses with the right gastro-epiploic artery. It distributes several ascending branches to both surfaces of the stomach; others descend to supply the greater omentum and anastomose with branches of the middle colic artery.

Applied Anatomy.—Embolism of branches of the lienal artery is tolerably common in heart disease, the embolus coming from the left side of the heart. It is characterised by the occurrence of a sudden sharp pain or 'stitch' in the splenic region, with subsequent local enlargement of the spleen from the formation of an infarct in its substance.

SUPERIOR MESENTERIC ARTERY (fig. 641)

The **superior mesenteric artery** supplies the whole of the small intestine except the superior part of the duodenum; it also supplies the cæcum and the ascending colon and about one-half of the transverse colon. It arises from the front of the aorta about 1.25 cm. below the coeliac artery, and is crossed at its origin by the lienal vein and the neck of the pancreas. It passes downwards and forwards, anterior to the processus uncinatus of the head of the pancreas and the inferior part of the duodenum, and descends between the layers of the mesentery to the right iliac fossa, where, considerably diminished in size, it anastomoses with one of its own branches, viz. the ileocolic artery. In its course it crosses in front of the inferior vena cava, the right ureter, and Psoas major, and forms an arch, the convexity of which is directed forwards and downwards, to the left side. It is accompanied by the superior mesenteric vein, which lies to its right side, and is surrounded by the superior mesenteric plexus of nerves. Its branches are:

Inferior pancreaticoduodenal.
Jejunal and ileal.

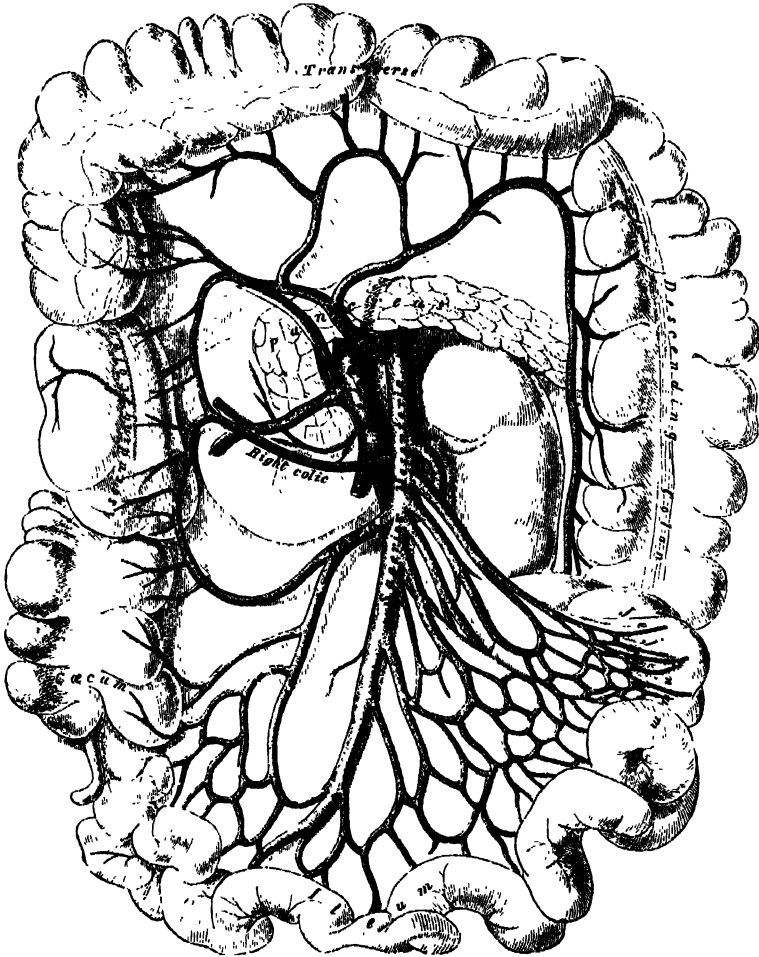
Ileocolic.
Right colic.

Middle colic.

The **inferior pancreaticoduodenal artery** springs from the superior mesenteric artery or from its first jejunal branch, opposite the upper border of the inferior part of the duodenum. It courses to the right between the head of the pancreas and duodenum, and then ascends to anastomose with the superior pancreaticoduodenal artery. It distributes branches to the head of the pancreas and to the descending and inferior parts of the duodenum.

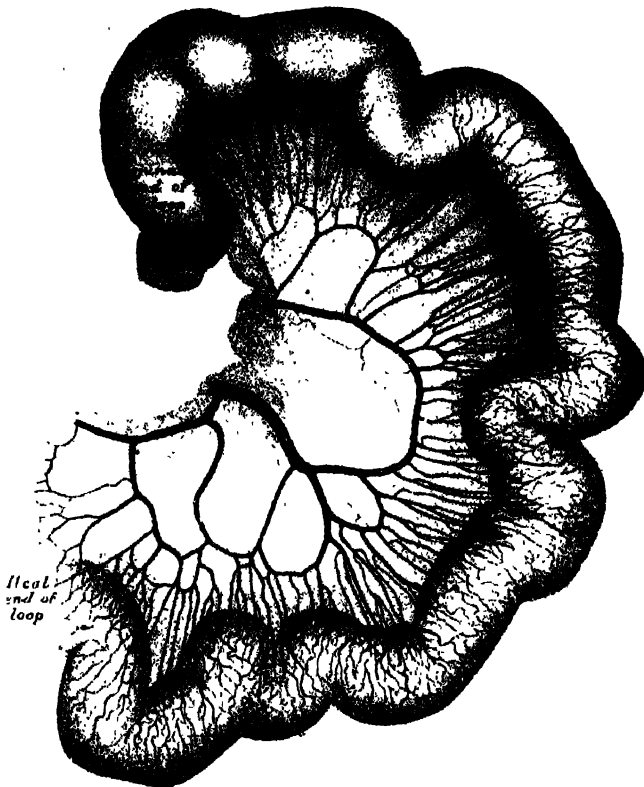
The **jejunal and ileal arteries** (*vasa intestini tenuis*) arise from the left side of the superior mesenteric artery. They are usually from twelve to fifteen in

FIG. 641.--The superior mesenteric artery and its branches.



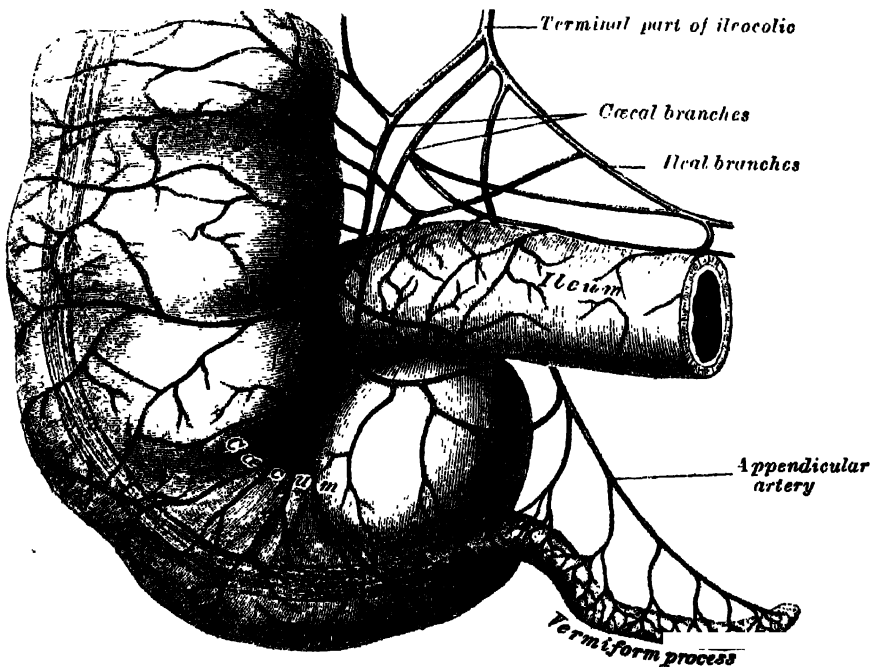
number, and are distributed to the jejunum and ileum. They run nearly parallel with one another between the layers of the mesentery, each vessel dividing into two branches, which unite with adjacent branches, forming a series of arches, the convexities of which are directed towards the intestine (fig. 642). From this first set of arches branches arise, which unite with similar branches from above and below, and thus a second series of arches is formed; from the lower branches of the artery, a third, a fourth, and even a fifth series of arches may be formed, diminishing in size the nearer they approach the intestine. In the short, upper part of the mesentery only one set of arches exists, but as the depth of the mesentery increases, second, third, fourth, and even fifth groups are developed. From the terminal arches numerous small straight vessels arise which encircle the intestine and are distributed to it. From the jejunal and ileal arteries small branches are given off to the lymph-glands and other structures between the layers of the mesentery.

FIG. 642.—Loop of small intestine showing distribution of intestinal arteries.
(From a preparation by Hamilton Drummond.)



The vessels were injected while the gut was *in situ*; the gut was then removed, and an x-ray photograph taken.

FIG. 643.—Arteries of caecum and vermiform process.



The **ileocolic artery** is the lowest branch arising from the concavity of the superior mesenteric artery. It passes downwards and to the right behind the peritoneum, towards the right iliac fossa, where it divides into a superior and an inferior branch; the superior branch anastomoses with the right colic artery, the inferior with the end of the superior mesenteric artery.

The inferior branch of the ileocolic runs towards the upper border of the ileocolic junction and supplies the following branches (fig. 643): (a) *colic*, which pass upwards on the ascending colon; (b) *anterior and posterior cæcal*, which are distributed to the front and back of the cæcum; (c) an *appendicular artery*, which descends behind the termination of the ileum and enters the mesenteriole of the vermiform process; it runs near the free margin of this mesenteriole and ends in branches which supply the vermiform process; and (d) *ileal*, which runs upwards and to the left on the lower part of the ileum, and anastomose with the termination of the superior mesenteric artery.

The **right colic artery** arises from about the middle of the concavity of the superior mesenteric artery, or from a stem common to it and the ileocolic. It passes to the right behind the peritoneum, and in front of the right testicular (or ovarian) artery and vein, the right ureter, and the Psoas major, towards the middle of the ascending colon; sometimes the vessel lies at a higher level, and crosses the descending part of the duodenum and the lower end of the right kidney. At the colon it divides into a descending branch, which anastomoses with the ileocolic artery, and an ascending branch, which anastomoses with the middle colic artery. These branches form arches, from the convexity of which vessels are distributed to the ascending colon.

The **middle colic artery** arises from the superior mesenteric artery just below the pancreas and, passing downwards and forwards between the layers of the transverse mesocolon, divides into a right and a left branch; the former anastomoses with the right colic artery; the latter with the left colic artery, a branch of the inferior mesenteric artery. The arches thus formed are placed about two fingers' breadth from the transverse colon, to which they distribute branches.

INFERIOR MESENTERIC ARTERY (fig. 644)

The **inferior mesenteric artery** supplies the left half of the transverse colon, the whole of the descending colon, the sigmoid colon, and the greater part of the rectum. It is smaller than the superior mesenteric, and arises from the aorta, about 3 or 4 cm. above its division into the common iliacs, and close to the lower border of the inferior part of the duodenum. It descends behind the peritoneum, lying at first anteriorly to, and then on the left side of, the aorta. It crosses the left common iliac artery on the medial side of the left ureter, and is continued into the lesser pelvis as the *superior hæmorrhoidal artery*, between the two layers of the sigmoid mesocolon, and ends on the upper part of the rectum. Its branches are:

Left colic.

Sigmoid.

Superior hæmorrhoidal.

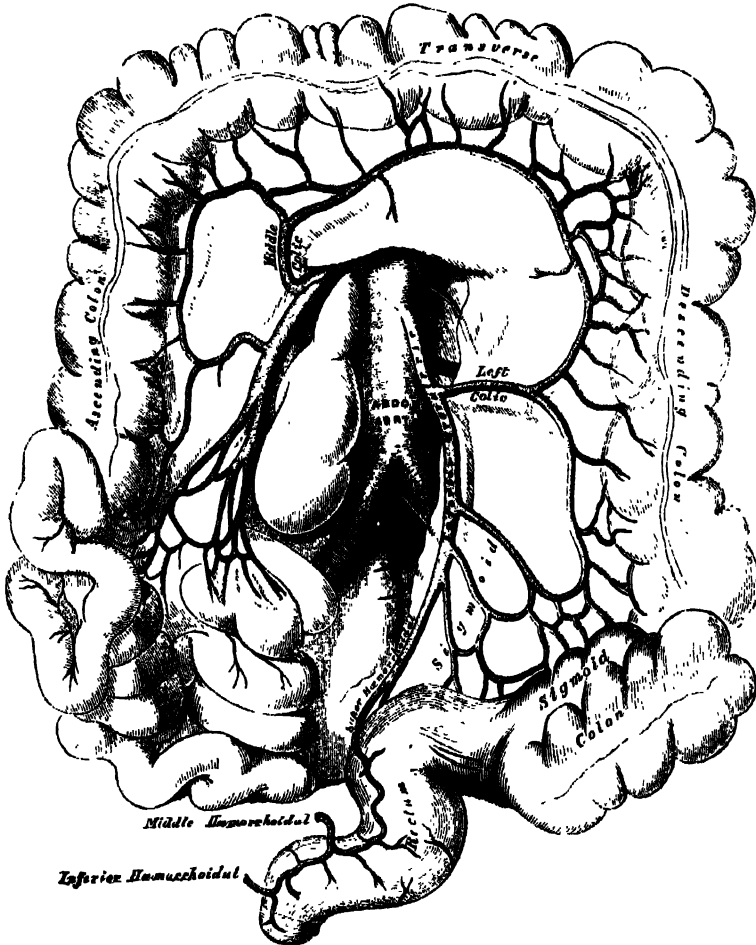
The **left colic artery** runs to the left behind the peritoneum and in front of the Psoas major, and, after a short but variable course, divides into an ascending and a descending branch; the trunk or the branches of the artery cross the left ureter and left testicular vessels. The ascending branch passes in front of the left kidney and between the two layers of the transverse mesocolon where it ends by anastomosing with the middle colic artery; the descending branch anastomoses with the highest sigmoid artery. From the arches formed by these anastomoses branches are distributed to the descending colon and the left half of the transverse colon.

The **sigmoid arteries** (fig. 645), two or three in number, run obliquely downwards and to the left behind the peritoneum and in front of the Psoas major, ureter, and testicular vessels. Their branches supply the lower part of the descending colon and the sigmoid colon, anastomosing above with the left colic artery, and below with the superior hæmorrhoidal artery.

The **superior hæmorrhoidal artery** (fig. 645), the continuation of the inferior mesenteric artery, descends into the pelvis between the layers of the sigmoid mesocolon, crossing, in its course, the left common iliac vessels. It divides, opposite the third sacral vertebra, into two branches; these descend one on either side of the

rectum, and supply its mucous membrane as far as the anal canal, and the upper part of its muscular coat; about 10 or 12 cm. from the anus the two arteries break up into several small branches. These pierce the muscular coat of the bowel and run downwards, as straight vessels placed at regular intervals from each other, in the wall of the gut between its muscular and mucous coats, to the level of the Sphincter ani internus; here they form a series of loops around the lower end of the rectum, and communicate with the middle hæmorrhoidal branches of the hypogastric artery, and with the inferior hæmorrhoidal branches of the internal pudendal artery.

FIG. 644.—The inferior mesenteric artery and its branches.



Applied Anatomy.—Embolism of the mesenteric arteries produces acute and severe symptoms, of which the chief are abdominal pain and tenderness, nausea and vomiting, diarrhœa or constipation; blood is found in the stools of nearly half the patients. In many cases the symptoms closely resemble those of intestinal obstruction.

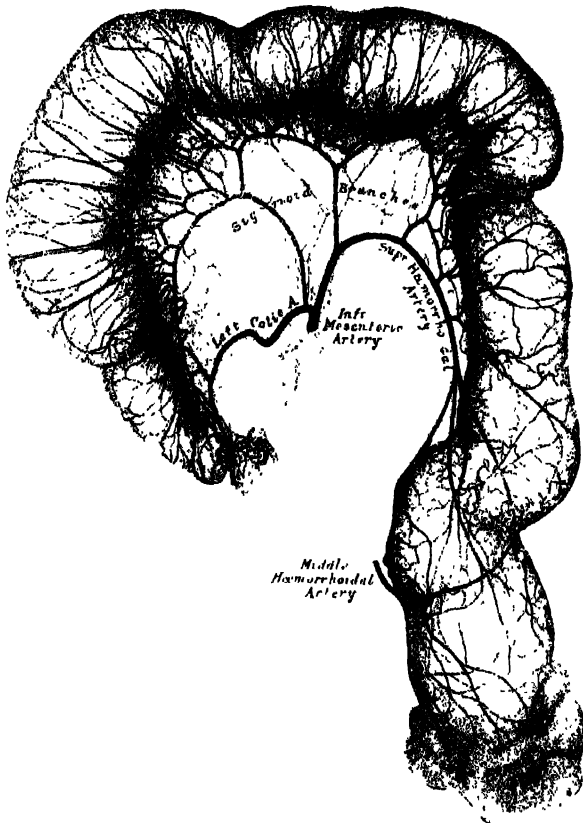
MIDDLE SUPRARENAL ARTERIES

The **middle suprarenal arteries** are two small vessels which arise, one from either side of the aorta, opposite the superior mesenteric artery. Each passes lateralwards and slightly upwards, over the crus of the Diaphragm, to the suprarenal gland, where it anastomoses with suprarenal branches of the inferior phrenic and renal arteries.

RENAL ARTERIES (fig. 638)

The renal arteries are two large trunks, which arise from the sides of the aorta, immediately below the superior mesenteric artery. Each is directed across the crus of the Diaphragm, so as to form nearly a right angle with the aorta. The *right* is longer than the left, on account of the position of the aorta; it passes behind the inferior vena cava, the right renal vein, the head of the pancreas, and the descending part of the duodenum. The *left* is a little higher than the right; it lies behind the left renal vein, the body of the pancreas

FIG. 645.—Sigmoid colon and rectum, showing distribution of branches of inferior mesenteric artery, and their anastomoses. (From a preparation by Hamilton Drummond.)



Prepared in same manner as Fig. 642.

and the lienal vein, and is crossed by the inferior mesenteric vein. Before reaching the hilum of the kidney, each artery divides into four or five branches; most of these lie between the renal vein and ureter, the vein being in front, the ureter behind, but one or more branches are usually situated behind the ureter. Each vessel gives off some small *inferior suprarenal branches* to the suprarenal gland, and supplies twigs to the ureter and the surrounding cellular tissue and muscles.

One or two accessory renal arteries are frequently found, more especially on the left side: they usually arise from the aorta, and may come off above or below the main artery, the former being the more common position. Instead of entering the kidney at the hilum, they usually pierce the upper or lower part of the kidney.

TESTICULAR ARTERIES (fig. 638)

The **testicular arteries** are two long slender vessels which arise from the front of the aorta a little below the renal arteries. Each passes obliquely downwards and lateralwards behind the peritoneum, resting on the Psoas major; the right artery lies in front of the inferior vena cava and behind the middle colic and ileocolic arteries and the terminal part of the ileum; the left artery passes behind the left colic and sigmoid arteries, and the iliac part of the descending colon. Each artery crosses obliquely over the ureter and the lower part of the external iliac artery to reach the abdominal inguinal ring, through which, accompanied by the other constituents of the spermatic cord, it enters the inguinal canal and passes to the scrotum, where it becomes tortuous and divides into several branches. Two or three of these accompany the ductus deferens, and supply the epididymis, anastomosing with the artery of the ductus deferens; others pierce the back part of the tunica albuginea, and supply the substance of the testis. The testicular artery supplies one or two small branches to the ureter, and in the inguinal canal gives one or two twigs to the Cremaster muscle.

OVARIAN ARTERIES

The **ovarian arteries** in the female correspond to the testicular arteries in the male. They supply the ovaries, are shorter than the testicular arteries, and end in the pelvic cavity. The origin and course of the first part of each artery are the same as those of the testicular artery, but on arriving at the upper opening of the lesser pelvis the artery passes medialwards between the two layers of the broad ligament of the uterus below the uterine tube. At the level of the ovary it runs backwards in the mesovarium and breaks up into branches which are distributed to the ovary. Small branches are given to the ureter and the uterine tube, and one passes on to the side of the uterus, and unites with the uterine artery. Other offsets are continued on the round ligament of the uterus, through the inguinal canal, to the skin of the labium majus and groin.

At an early period of foetal life, when the testes or ovaries lie by the side of the vertebral column, below the kidneys, the testicular and ovarian arteries are short; but with the descent of the testicles into the scrotum, and of the ovaries into the pelvis, the arteries are gradually lengthened.

INFERIOR PHRENIC ARTERIES (fig. 638)

The **inferior phrenic arteries** are two small vessels which supply the Diaphragm. They present much variety in their origins; they may arise separately from the front of the aorta, immediately above the coeliac artery, or by a common trunk, which may spring either from the aorta or from the coeliac artery; sometimes one artery is derived from the aorta, and the other from one of the renal arteries. They diverge from one another across the crura of the Diaphragm, and then run obliquely upwards and lateralwards upon its under surface. The left phrenic passes behind the oesophagus, and runs forwards on the left side of the oesophageal hiatus. The right phrenic passes behind the inferior vena cava, and along the right side of the foramen which transmits that vein. Near the posterior part of the central tendon of the Diaphragm each vessel divides into a medial and a lateral branch. The medial branch curves forwards, and anastomoses with its fellow of the opposite side, and with the musculophrenic and pericardiophrenic arteries. The lateral branch passes towards the side of the thorax, and anastomoses with the lower intercostal arteries, and with the musculophrenic artery. The lateral branch of the right artery gives off a few twigs to the inferior vena cava; and the left artery sends some branches to the oesophagus. Each vessel gives off *superior branches* to the suprarenal gland of its own side. The liver and the spleen also receive a few twigs from the right and left vessels respectively.

LUMBAR ARTERIES

The **lumbar arteries** are in series with the intercostals. They are usually four in number on either side, and arise from the back of the aorta, opposite the bodies of the upper four lumbar vertebræ. A fifth pair, small in size, is occasionally present: it arises from the middle sacral artery. They run lateralwards and backwards on the bodies of the lumbar vertebræ, behind the sympathetic trunk, to the intervals between the adjacent transverse processes, and are then continued into the abdominal wall. The arteries of the right side pass behind the inferior vena cava, and the upper two on either side run behind the corresponding crus of the Diaphragm. The arteries of both sides pass beneath the tendinous arches which give origin to the Psoas major, and are continued behind this muscle and the lumbar plexus. They then cross the Quadratus lumborum, the upper three arteries running behind, the last usually in front of it. At the lateral border of the Quadratus lumborum they pierce the posterior aponeurosis of the Transversus abdominis, and are carried forwards between this muscle and the Obliquus internus. They anastomose with one another and with the lower intercostal, subcostal, ilio-lumbar, deep iliac circumflex, and inferior epigastric arteries.

Branches. Each lumbar artery gives off a *posterior ramus* which passes backwards between the transverse processes, is distributed to the muscles and skin of the back, and furnishes a *spinal branch* which enters the vertebral canal and supplies its contents, anastomosing with the arteries above and below it, and with the artery of the opposite side. Branches are also given by the lumbar arteries and their posterior rami to the neighbouring muscles.

MIDDLE SACRAL ARTERY (fig. 638)

The **middle sacral artery** is a small vessel, which arises from the back of the aorta, a little above its bifurcation. It descends in the middle line in front of the fourth and fifth lumbar vertebræ, the sacrum and coccyx, and ends in the glomus coccygeum (coccygeal gland); it is crossed by the left common iliac vein. Minute branches are said to pass from it to the posterior surface of the rectum. On the last lumbar vertebra it anastomoses with the lumbar branch of the ilio-lumbar artery; in front of the sacrum it anastomoses with the lateral sacral arteries, and sends offsets into the anterior sacral foramina.

COMMON ILIAC ARTERIES (figs. 638, 646)

The abdominal aorta divides, on the left side of the body of the fourth lumbar vertebra, into the two **common iliac arteries** which diverge from the termination of the aorta, pass downwards and lateralwards, and divide opposite the intervertebral fibrocartilage between the last lumbar vertebra and the sacrum, into two branches, the *external iliac* and *hypogastric arteries*: the former supplies the greater part of the lower extremity; the latter, the viscera and parietes of the pelvis, and the glutæal region.

The **right common iliac artery** (fig. 646), about 5 cm. long, passes obliquely across the body of the last lumbar vertebra. *In front* of it are the peritoneum, the small intestine, branches of the sympathetic nerves, and, at its point of division, the ureter. *Behind*, it is separated from the bodies of the fourth and fifth lumbar vertebræ, and the intervening fibrocartilage by the terminations of the two common iliac veins and the commencement of the inferior vena cava. *Laterally*, it is in relation, above, with the inferior vena cava and the right common iliac vein; below, with the Psoas major. *Medial* to it, above, is the left common iliac vein.

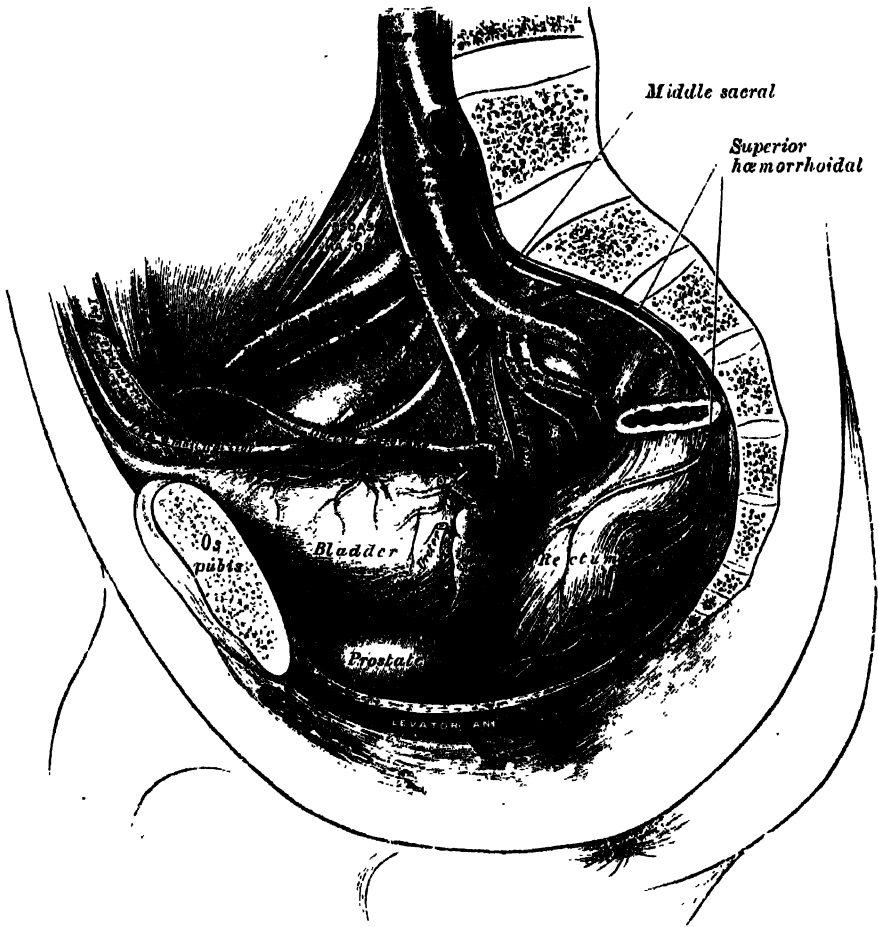
The **left common iliac artery**, about 4 cm. long, is in relation, *in front*, with the peritoneum, the small intestine, branches of the sympathetic nerves, and the superior hæmorrhoidal artery, and is crossed at its point of bifurcation by the ureter. It rests on the bodies of the fourth and fifth lumbar vertebræ, and the intervening fibrocartilage. The left common iliac vein lies partly

medial to, and partly behind, the artery; laterally, the artery is in relation with the Psoas major.

Branches.—The common iliac arteries give off small branches to the peritoneum, Psoas major, ureters, and the surrounding areolar tissue, and occasionally give origin to the ilio lumbar or to accessory renal arteries.

Peculiarities.—The point of origin of the common iliac arteries varies according to the bifurcation of the aorta, which in most cases occurs either upon the fourth lumbar vertebra, or upon the fibrocartilage between it and the fifth.

FIG. 646.—The arteries of the pelvis. Right side



The common iliac arteries may divide above or below the usual level.

The length of the arteries varies from 3.5 to 7.5 cm. In rare instances, the right common iliac has been found wanting, the external iliac and hypogastric arteries arising directly from the aorta.

Applied Anatomy.—The application of a ligature to the common iliac artery may be required on account of aneurysm or hemorrhage, implicating the external iliac or hypogastric arteries. The easiest and best method of tying the artery is by a transperitoneal route. The abdomen is opened, the intestines are drawn aside and the peritoneum covering the artery divided; the sheath is then opened and the needle passed from the medial to the lateral side. On the right side great care must be exercised in passing the needle, since both the common iliac veins lie behind the artery. After the vessel has been tied, the incision in the peritoneum over the artery should be sutured.

Collateral Circulation.—The principal agents in carrying on the collateral circulation after the application of a ligature to the common iliac are: the anastomoses of the hemorrhoidal branches of the hypogastric artery with the superior hæmorrhoidal

branches from the inferior mesenteric artery; of the uterine, ovarian, and vesical arteries of the opposite sides; of the lateral sacral arteries with the middle sacral artery; of the inferior epigastric artery with the internal mammary, lower intercostal, and lumbar arteries; of the deep iliac circumflex artery with the lumbar arteries; of the ilio-lumbar artery with the last lumbar artery; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the inferior epigastric artery.

HYPOGASTRIC ARTERY (fig. 646)

The **hypogastric or internal iliac artery**, about 4 cm. long, arises at the bifurcation of the common iliac, opposite the lumbosacral articulation; it descends to the upper margin of the greater sciatic foramen where it divides into an *anterior* and a *posterior* trunk.

Relations.—It is in relation *in front* with the ureter; *behind*, with the internal iliac vein, the lumbosacral nerve-trunk, and the Piriformis muscle; *laterally*, near its origin, with the external iliac vein, which lies between it and the Psoas major muscle; lower down, with the obturator nerve.

In the fetus, the hypogastric artery is twice as large as the external iliac artery, and is the direct continuation of the common iliac artery. It ascends on the back of the anterior wall of the abdomen to the umbilicus, converging towards its fellow of the opposite side. Having passed through the umbilical opening, the two arteries, now termed *umbilical*, enter the umbilical cord, where they are coiled round the umbilical vein, and ultimately ramify in the placenta.

At birth, when the placental circulation ceases, the pelvic portion only of the artery remains patent and constitutes the hypogastric artery and the first part of the superior vesical artery of the adult; the remainder of the vessel is converted into a solid fibrous cord, the *lateral umbilical ligament* (obliterated hypogastric artery), which extends from the pelvis to the umbilicus.

Peculiarities.—The length of the hypogastric and common iliac arteries bear an inverse proportion to each other.

The place of division of the hypogastric varies between the upper margin of the sacrum and the upper border of the greater sciatic foramen.

Applied Anatomy.—The application of a ligature to the hypogastric artery may be required in cases of aneurysm or hemorrhage affecting one of its branches. The vessel is best secured by an abdominal section in the median line, the vessel being reached through the peritoneal cavity. It should be remembered that the vein lies behind, and, on the right side, a little lateral to the artery; the ureter lies in front of it.

Collateral Circulation.—The circulation after ligature of the hypogastric artery is carried on by the anastomoses of the uterine and ovarian arteries; of the vesical arteries of the two sides; of the hemorrhoidal branches of the hypogastric artery with those from the inferior mesenteric artery; of the pubic branch of the obturator artery with the vessel of the opposite side, and with the inferior epigastric and medial femoral circumflex arteries; of the circumflex and perforating branches of the arteria profunda femoris with the inferior gluteal artery; of the superior gluteal artery with the posterior branches of the lateral sacral arteries; of the ilio-lumbar with the last lumbar artery; of the middle sacral arteries with the lateral sacral artery; and of the iliac circumflex with the ilio-lumbar and superior gluteal arteries.*

The branches of the hypogastric artery are :

From the Anterior Trunk.

Superior vesical.
Inferior vesical.
Middle hemorrhoidal.
Obturator.

Uterine. } *In the female.*
Vaginal. }

Internal pudendal.
Inferior gluteal.

From the Posterior Trunk.

Ilio-lumbar.
Lateral sacral.
Superior gluteal.

The **superior vesical artery** supplies numerous branches to the upper part of the bladder. From one of these a slender vessel, the *artery to the ductus deferens*,

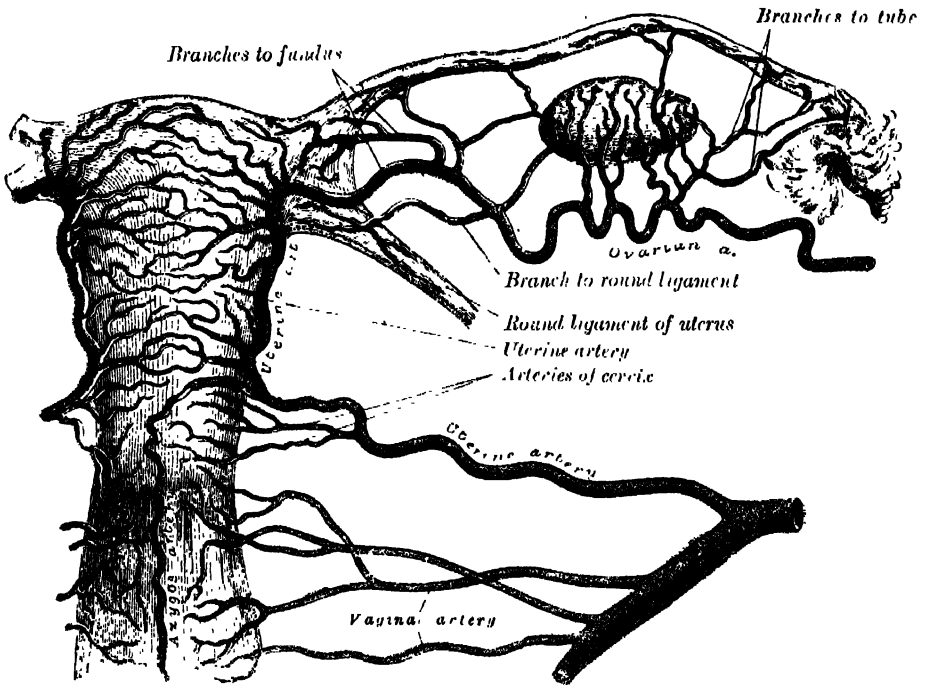
* For a description of a case in which Owen made a dissection ten years after ligature of the hypogastric artery, see *Med.-Chir. Trans.* vol. xvi.

takes origin and accompanies the ductus deferens in its course to the testis, where it anastomoses with the testicular artery. Other branches supply the ureter. The first part of the superior vesical artery is the proximal, pervious portion of the foetal hypogastric artery.

The **inferior vesical artery** frequently arises in common with the middle hæmorrhoidal artery, and is distributed to the fundus of the bladder, the prostate, the vesiculæ seminales and the lower part of the ureter. The branches to the prostate communicate with the corresponding vessels of the opposite side.

The **middle hæmorrhoidal artery** usually arises with the preceding vessel. It is distributed to the muscular coats of the rectum, anastomosing with the inferior vesical artery and with the superior and inferior hæmorrhoidal arteries. It gives offsets to the vesiculæ seminales and prostate.

FIG. 647.—The arteries of the internal organs of generation of the female seen from behind. (After Hyrtl.)



The **uterine artery** (fig. 647) runs medialwards on the Levator ani and towards the cervix uteri; about 2 cm. from the cervix it crosses above and in front of the ureter, to which it supplies a small branch. Reaching the side of the uterus it ascends in a tortuous manner between the two layers of the broad ligament to the junction of the uterine tube and uterus. It then runs lateralwards towards the hilum of the ovary, and ends by joining with the ovarian artery. It supplies branches to the cervix uteri and others which descend on the vagina; the latter anastomose with branches of the vaginal arteries and form with them two median longitudinal vessels—the *azygos arteries of the vagina*—one of which descends in front of, and the other behind, the vagina. It supplies numerous branches to the body of the uterus, and from its terminal portion twigs are distributed to the uterine tube and the round ligament of the uterus.

The **vaginal artery** usually corresponds to the inferior vesical in the male; it descends upon the vagina, supplying its mucous membrane, and sends branches to the bulb of the vestibule, the fundus of the bladder, and the contiguous part of the rectum. It assists in forming the azygos arteries of the vagina, and is frequently represented by two or three branches.

The **obturator artery** passes forwards and downwards on the lateral wall of the pelvis, to the upper part of the obturator foramen, and, escaping from the

pelvic cavity through the obturator canal, it divides into an anterior and a posterior branch. In the pelvic cavity this vessel is in relation, laterally, with the obturator fascia which separates it from the Obturator internus muscle; medially, with the ureter, ductus deferens, and peritoneum; the obturator nerve is above it and the obturator vein below it.

Branches.—*Inside the pelvis*, the obturator artery gives off (a) *iliac branches* to the iliac fossa; these supply the bone and the Iliacus, and anastomose with the ilio-lumbar artery; (b) a *vesical branch* which runs medialwards to the bladder; and (c) a *pubic branch* which springs from the vessel just before it leaves the pelvic cavity; this branch ascends upon the back of the os pubis and communicates with the corresponding vessel of the opposite side, and with the pubic branch of the inferior epigastric artery.

Outside the pelvis, the obturator artery divides at the upper margin of the obturator foramen, into an anterior and a posterior branch which encircle the foramen under cover of the Obturator externus.

The *anterior branch* runs forwards on the outer surface of the obturator membrane and then curves downwards along the anterior margin of the foramen. It distributes branches to the Obturator externus, Pectineus, Adductores, and Gracilis, and anastomoses with the posterior branch, and with the medial femoral circumflex artery.

The *posterior branch* follows the posterior margin of the foramen and turns forwards on the inferior ramus of the ischium where it anastomoses with the anterior branch. It gives twigs to the muscles attached to the ischial tuberosity and anastomoses with the inferior gluteal artery. It also supplies an articular branch which enters the hip-joint through the acetabular notch, ramifies in the fat at the bottom of the acetabulum and sends a twig along the ligamentum teres to the head of the femur.

FIG. 648.—Variations in the origin and course of obturator artery.



Peculiarities.—In about 28 per cent. of cases the obturator artery springs from the inferior epigastric and descends almost vertically to the upper part of the obturator foramen. The artery in this course usually lies in contact with the external iliac vein, and on the lateral side of the femoral ring (fig. 648A); in such cases it would not be endangered in the operation for strangulated femoral hernia. Occasionally, however, it curves along the free margin of the lacunar ligament (fig. 648B), and if in such circumstances a femoral hernia occurred, the vessel would almost completely encircle the neck of the hernial sac, and would be in great danger of being wounded if an operation were performed for strangulation. It sometimes arises from the main stem or from the posterior trunk of the hypogastric artery, or it may spring from the superior gluteal artery; occasionally it arises from the external iliac artery.

The **internal pudendal artery**, the smaller of the two terminal branches of the anterior trunk of the hypogastric artery, supplies the external organs of generation. Though the course of the artery is the same in the two sexes, the vessel is smaller in the female than in the male, and the distribution of its branches somewhat different. The description of its arrangement in the male will first be given, and subsequently the differences which it presents in the female will be mentioned.

The **internal pudendal artery in the male** passes downwards and lateralwards to the lower border of the greater sciatic foramen, and emerges from the pelvis between the Piriformis and Coccygeus; it then crosses the ischial spine, and enters the perineum through the lesser sciatic foramen. The artery now crosses the Obturator internus, along the lateral wall of the ischio-rectal fossa, being situated about 4 cm. above the lower margin of the ischial tuberosity. It gradually approaches the margin of the inferior ramus of the ischium and passes forwards between the two layers of the fascia of the urogenital diaphragm; it then runs forwards along the medial margin of the inferior ramus of the os pubis, and at a distance of about 1.25 cm. behind the pubic arcuate ligament it pierces the inferior

fascia of the urogenital diaphragm and divides into the *dorsal* and *deep arteries of the penis*.

Relations.—Within the pelvis, it lies in front of the Piriformis muscle, the sacral plexus of nerves, and the inferior gluteal artery. As it crosses the ischial spine, it is covered by the Gluteus maximus and overlapped by the sacrotuberous ligament. Here the pudendal nerve lies to the medial side, and the nerve to the Obturator internus to the lateral side, of the vessel. In the perineum it lies on the lateral wall of the ischiorectal fossa in a canal (*Alcock's canal*) formed by the splitting of the obturator fascia; it is accompanied by a pair of venæ comitantes and the pudendal nerve.

Branches.—The branches of the internal pudendal artery (figs. 649, 650) are :

Muscular.

Inferior hæmorrhoidal.

Perineal.

Artery of the urethral bulb.

Urethral.

Deep artery of the penis.

Dorsal artery of the penis.

The *muscular branches* consist of two sets : one given off in the pelvis; the other, as the vessel crosses the ischial spine. The first set consists of several small offsets which supply the Levator ani, the Obturator internus, the Piriformis, and the Coccygeus. The branches of the second set are distributed to the Gluteus maximus and external rotator muscles; they anastomose with branches of the inferior gluteal artery.

The *inferior hæmorrhoidal artery* arises from the internal pudendal as it passes above the ischial tuberosity. Piercing the wall of Alcock's canal it divides into two or three branches which cross the ischiorectal fossa, and are distributed to the muscles and integument of the anal region, and send offshoots round the lower edge of the Gluteus maximus to the skin of the buttock. They anastomose with the corresponding vessels of the opposite side, with the superior and middle hæmorrhoidal arteries, and with the perineal artery.

The *perineal artery* arises from the internal pudendal artery, in front of the preceding branches, and turns upwards, crossing either over or under the Transversus perinei superficialis, and runs forwards, parallel to the pubic arch, in the interspace between the Bulbocavernosus and Ischioavernosus, both of which it supplies, and finally divides into several *posterior scrotal branches* which are distributed to the skin and dartos tunic of the scrotum. As it crosses the Transversus perinei superficialis it gives off the *transverse perineal artery* which runs transversely on the cutaneous surface of the muscle, and anastomoses with the corresponding vessel of the opposite side and with the perineal and inferior hæmorrhoidal arteries. It supplies the Transversus perinei superficialis and the structures between the anus and the urethral bulb.

The *artery of the urethral bulb* is a short vessel of relatively large calibre which arises from the internal pudendal artery between the two layers of fascia of the urogenital diaphragm; it passes medialwards, pierces the inferior fascia of the urogenital diaphragm, and gives off branches which ramify in the bulb of the urethra and in the posterior part of the corpus cavernosum urethrae. It supplies a small branch to the bulbo-urethral gland.

The *urethral artery* arises a short distance in front of the artery of the urethral bulb. It runs forwards and medialwards, pierces the inferior fascia of the urogenital diaphragm and enters the corpus cavernosum urethrae, in which it is continued forwards to the glans penis.

The *deep artery of the penis* (artery of the corpus cavernosum penis), one of the terminal branches of the internal pudendal artery, arises from that vessel while it is situated between the two fasciæ of the urogenital diaphragm; it pierces the inferior fascia, and, entering the crus penis obliquely, runs forwards in the centre of the corpus cavernosum penis, to which its branches are distributed.

The *dorsal artery of the penis* ascends between the crus penis and the pubic symphysis, and, piercing the inferior fascia of the urogenital diaphragm, passes between the two layers of the suspensory ligament of the penis, and runs forwards on the dorsum of the penis to the glans, where it divides into two branches, which supply the glans and prepuce. On the penis, it lies between the dorsal nerve and deep dorsal vein, the former being on its lateral side. It supplies the skin and the fibrous sheath of the corpus cavernosum penis, sending branches through the sheath to anastomose with the deep artery of the penis.

The *internal pudendal artery in the female* is smaller than in the male. Its origin and course are similar, and there is considerable analogy in the distribution of its branches. The perineal artery supplies the labia pudendi; the artery of the bulb is distributed to the bulbos vestibuli and the erectile tissue of the vagina; the deep artery of the clitoris supplies the corpus cavernosum clitoridis; the dorsal artery of the clitoris gives branches to the dorsum of that organ, and ends in the glans and prepuce of the clitoris.

FIG. 649.—The superficial branches of the internal pudendal artery.

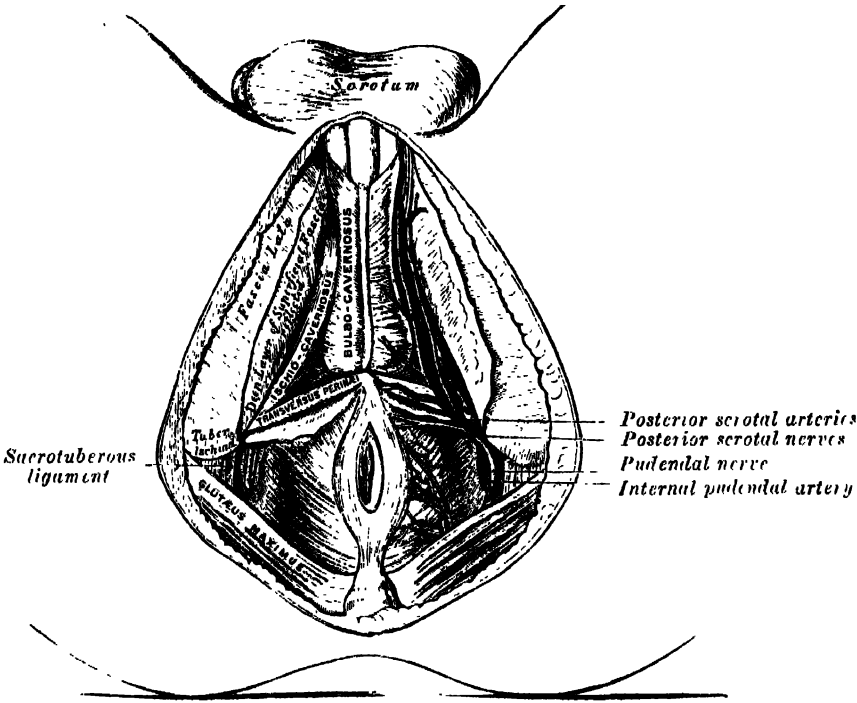
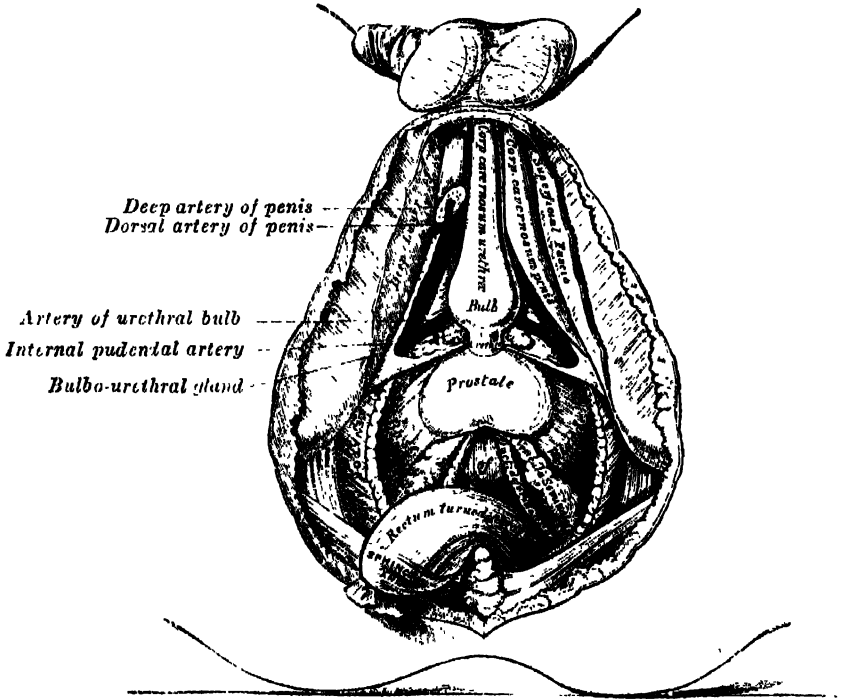


FIG. 650.—The deeper branches of the internal pudendal artery.



Peculiarities.—The internal pudendal artery is sometimes relatively small, or fails to give off one or two of its usual branches; in such cases the deficiency is supplied by branches derived from an additional vessel, the *accessory pudendal*, which generally arises from the internal pudendal artery before its exit from the greater sciatic foramen. It passes forwards along the lower part of the bladder and across the side of the prostate to the root of the penis, where it perforates the urogenital diaphragm, and gives off the branches usually derived from the internal pudendal artery. The deficiency most frequently met with is that in which the internal pudendal artery ends as the artery of the urethral bulb, the dorsal and deep arteries of the penis being derived from the accessory pudendal artery. The internal pudendal artery may also end as the perineal, the artery of the urethral bulb being derived, with the other two branches, from the accessory vessel. Occasionally the accessory pudendal artery is derived from one of the other branches of the hypogastric artery, most frequently the inferior vesical or the obturator.

The **inferior gluteal artery** (sciatic artery) (fig. 651), the larger of the two terminal branches of the anterior trunk of the hypogastric artery, is distributed chiefly to the buttock and back of the thigh. It passes down on the sacral plexus of nerves and the Piriformis, behind the internal pudendal artery, to the lower part of the greater sciatic foramen, through which it escapes from the pelvis between the Piriformis and Coccygeus. It then descends in the interval between the greater trochanter of the femur and the tuberosity of the ischium, accompanied by the sciatic and posterior femoral cutaneous nerves, and covered by the Glutæus maximus; it is continued down the back of the thigh, supplying the skin, and anastomosing with branches of the perforating arteries.

Inside the pelvis it distributes (a) branches to the Piriformis, Coccygeus, and Levator ani; (b) branches which supply the fat around the rectum, and occasionally take the place of the middle hæmorrhoidal artery; and (c) vesical branches to the fundus of the bladder, vesiculæ seminales, and prostate.

Outside the pelvis it gives off the following branches:

Muscular branches supply the Glutæus maximus, the external rotators of the thigh, and the muscles attached to the tuberosity of the ischium; they anastomose with the superior gluteal, internal pudendal, obturator and medial femoral circumflex arteries.

Coccygeal branches run medialwards, pierce the sacrotuberous ligament, and supply the Glutæus maximus and the structures on the back of the coccyx.

The *arteria comitans nervi ischiadici*, a long slender vessel, accompanies the sciatic nerve for a short distance; it then penetrates it, and runs in its substance to the lower part of the thigh.

An *anastomotic branch* is directed obliquely downwards across the external rotator muscles of the thigh, and assists in forming the so-called *crucial anastomosis* by joining with the first perforating and the medial and lateral femoral circumflex arteries.

An *articular branch*, generally derived from the anastomotic, is distributed to the capsule of the hip-joint.

Cutaneous branches are distributed to the skin of the buttock and back of the thigh.

The **iliolumbar artery**, a branch of the posterior trunk of the hypogastric artery turns upwards behind the obturator nerve and the external iliac vessels, to the medial border of the Psoas major, behind which it divides into a lumbar and an iliac branch.

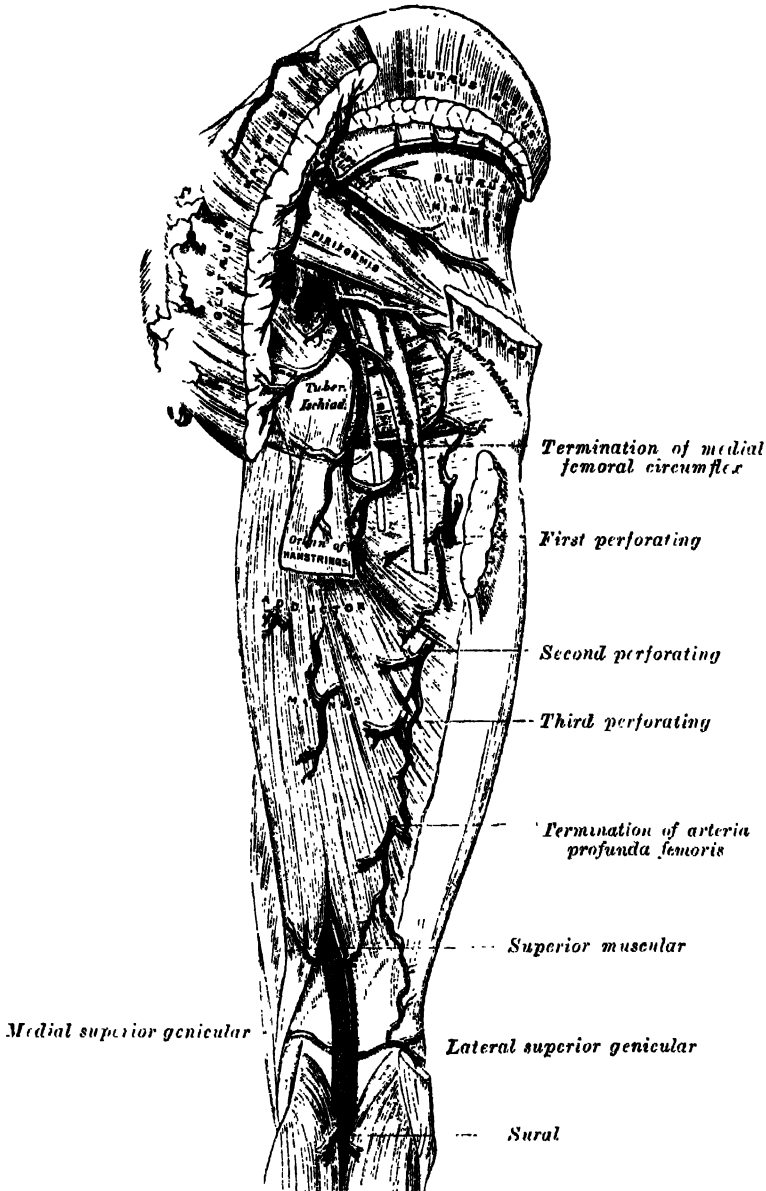
The *lumbar branch* supplies the Psoas major and Quadratus lumborum, anastomoses with the fourth lumbar artery, and sends a small *spinal branch* through the intervertebral foramen between the fifth lumbar vertebra and the base of the sacrum, into the vertebral canal to supply the cauda equina.

The *iliac branch* supplies the Iliacus; some offsets run between the muscle and the bone and anastomose with the iliac branches of the obturator artery; one of these enters an oblique canal to supply the bone, while others run along the crest of the ilium, distributing branches to the gluteal and abdominal muscles, and anastomosing in their course with the superior gluteal, iliac circumflex, and lateral femoral circumflex arteries.

The **lateral sacral arteries** (fig. 646) arise from the posterior division of the hypogastric artery; there are usually two, a superior and an inferior. The *superior* and larger passes medialwards, and, after anastomosing with branches from the middle sacral artery, enters the first or second anterior sacral foramen, supplies branches to the contents of the sacral canal, and, escaping by the corresponding posterior sacral foramen, is distributed to the skin and muscles on the dorsum of the sacrum, anastomosing with the superior gluteal. The *inferior* runs obliquely across the front of the Piriformis and the sacral nerves, to the medial side of the anterior sacral foramina, descends on the front of the sacrum, and anastomoses over the coccyx with the middle sacral artery and the opposite lateral sacral arteries.

Branches of it enter the anterior sacral foramina, and, after supplying the contents of the sacral canal, escape by the posterior sacral foramina, and are distributed to the muscles and skin on the dorsal surface of the sacrum, anastomosing with the glutæal arteries.

FIG. 651.—The arteries of the glutæal and posterior femoral regions.



The **superior glutæal artery** (fig. 651) is the largest branch of the hypogastric artery, and appears to be the continuation of the posterior division of that vessel. It is a short artery which runs backwards between the lumbosacral trunk and the first sacral nerve, and, passing out of the pelvis above the upper border of the Piriformis, immediately divides into a *superficial* and a *deep branch*. Within the pelvis it gives off a few branches to the Iliacus, Piriformis, and Obturator internus, and just previous to quitting the pelvis, a nutrient artery to the ilium.

The *superficial branch* enters the deep surface of the Glutæus maximus, and divides into numerous branches; some of these supply the muscle and anastomose

with the inferior gluteal, while others perforate the tendinous origin of the muscle, supply the skin covering the posterior surface of the sacrum, and anastomose with the posterior branches of the lateral sacral arteries.

The *deep branch* lies under the Glutæus medius and almost immediately subdivides into two. Of these, the *superior division* passes along the upper border of the Glutæus minimus to the anterior superior spine of the ilium, anastomosing with the deep iliac circumflex artery and the ascending branch of the lateral femoral circumflex artery. The *inferior division* crosses the Glutæus minimus obliquely to the greater trochanter, distributes branches to the Glutæi, and anastomoses with the lateral femoral circumflex artery; some branches pierce the Glutæus minimus and supply the hip-joint.

Applied Anatomy.—Either of the gluteal arteries may require to be ligatured for a wound, or for aneurysm, which is generally traumatic. The *superior gluteal artery* is ligatured by turning the patient two-thirds over on to his face and making an incision from the posterior superior spine of the ilium to the upper and posterior angle of the greater trochanter. This exposes the Glutæus maximus, and its fibres are to be separated through the whole thickness of the muscle and pulled apart with retractors. The contiguous margins of the Glutæus medius and Piriformis are now to be separated from each other, and the artery will be exposed emerging from the greater sciatic foramen. In ligature of the *inferior gluteal artery*, the incision should be made parallel with that for ligature of the superior gluteal but 4 cm. lower down. After the fibres of the Glutæus maximus have been separated, the vessel is to be sought at the lower border of the Piriformis: the sciatic nerve, which lies just above it, forms the chief guide to the artery.

EXTERNAL ILIAC ARTERY (fig. 646)

The **external iliac artery** is larger than the hypogastric artery, and runs obliquely downwards and lateralwards, along the medial border of the Psoas major, from the bifurcation of the common iliac artery to a point beneath the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis, where it enters the thigh and becomes the femoral artery.

Relations.—*In front and medially* the artery is in relation with the peritoneum and subperitoneal areolar tissue which separate the right artery from the termination of the ileum and frequently the vermiform process, and the left artery from the sigmoid colon and some coils of the small intestine. The beginning of the artery may be crossed by the ureter; in the female it is crossed by the ovarian vessels. The testicular vessels lie for some distance upon it near its termination, and it is crossed in this situation by the external spermatic branch of the genitofemoral nerve, the deep iliac circumflex vein, the ductus deferens in the male, and the round ligament of the uterus in the female. *Posteriorly*, it is separated from the medial border of the Psoas major by the iliac fascia. The external iliac vein lies partly behind the upper part of the artery, but is on the medial side of its lower part. *Lateral* to it is the Psoas major, from which it is separated by the iliac fascia. Numerous lymphatic vessels and lymph-glands lie on the front and sides of the vessel.

Applied Anatomy.—The application of a ligature to the external iliac may be required in cases of iliofemoral aneurysm (i.e. at the point where the artery passes beneath the inguinal ligament), or for an aneurysm or a wound of the femoral artery itself. The vessel may be secured in any part of its course, excepting near its upper end, which is to be avoided on account of the proximity of the hypogastric artery, and near its lower end, which should also be avoided on account of the proximity of its inferior epigastric and deep iliac circumflex branches. The operation may be performed by opening the abdomen and incising the peritoneum over the artery (*transperitoneal*); or by an incision in the iliac region, dividing all the structures down to the peritoneum, which is then separated unopened from the iliac fossa until the artery is reached (*retroperitoneal*).

The transperitoneal ligature is essentially similar to that described on p. 643 for the common iliac artery. The advantages of this operation are: (1) if it be found necessary, the common iliac artery can be ligatured instead of the external iliac without extension or modification of the incision; and (2) the vessel can be ligatured without in any way interfering with the sac of an aneurysm.

The retroperitoneal ligature may be performed by an incision above and parallel to the lateral half of the inguinal ligament. The abdominal muscles and transversalis fascia having been cautiously divided, the peritoneum should be separated from the iliac fossa and raised towards the pelvis; and on introducing the finger to the bottom of the wound, the artery may be felt pulsating along the medial border of the Psoas major. The

external iliac vein, generally found on the medial side of the artery, must be cautiously separated from it, and the aneurysm needle introduced on the medial side, between the artery and vein.

Collateral Circulation.—The principal anastomoses by which the collateral circulation is established, after ligature of the external iliac artery, are: the iliolumbar with the iliac circumflex arteries; the superior gluteal with the lateral femoral circumflex artery; the obturator with the medial femoral circumflex artery; the inferior gluteal with the circumflex and first perforating branches of the arteria profunda femoris; and the internal pudendal with the external pudendal artery. When the obturator artery arises from the inferior epigastric artery, it is supplied with blood by branches from either the hypogastric, the lateral sacral, or the internal pudendal arteries. The inferior epigastric artery receives its supply from the internal mammary and lower intercostal arteries, and from the hypogastric artery by the anastomoses of its branches with the obturator artery.*

Branches.—Besides supplying several small branches to the Psoas major and the neighbouring lymph-glands, the external iliac artery gives off the inferior epigastric and deep circumflex iliac branches.

The **inferior epigastric artery** (deep epigastric artery) (fig. 651) arises from the external iliac artery, immediately above the inguinal ligament. It curves forwards in the subperitoneal tissue, and then ascends obliquely along the medial margin of the abdominal inguinal ring; continuing its upward course, it pierces the transversalis fascia, passes in front of the linea semicircularis, and ascends between the Rectus abdominis and the posterior lamella of its sheath. It finally divides into numerous branches, which anastomose, above the umbilicus, with the superior epigastric branch of the internal mammary artery and with the lower intercostal arteries. As the inferior epigastric artery passes obliquely upwards from its origin it lies along the lower and medial margins of the abdominal inguinal ring, and behind the commencement of the spermatic cord. In the male the ductus deferens, and in the female the round ligament of the uterus, winds round the lateral and posterior aspects of the artery. It supplies the following branches:

The **external spermatic artery** (cremasteric artery) accompanies the spermatic cord, supplies the Cremaster and other coverings of the cord, and anastomoses with the testicular artery. In the female the external spermatic artery is very small and accompanies the round ligament of the uterus.

A **pubic branch** descends along the medial margin of the femoral ring to the back of the os pubis, and there anastomoses with the pubic branch of the obturator artery.

Branches are distributed to the abdominal muscles and peritoneum, and anastomose with the iliac circumflex and lumbar arteries.

Cutaneous branches perforate the tendon of the Obliquus externus, supply the skin and anastomose with branches of the superficial epigastric artery.

Peculiarities.—The origin of the inferior epigastric artery may take place from any part of the external iliac artery between the inguinal ligament and a point 6 cm. above it; or it may arise below this ligament, from the femoral artery. It frequently springs from the external iliac artery, by a common trunk with the obturator artery. Sometimes it arises from the obturator artery, the latter vessel being furnished by the hypogastric artery, or it may be formed of two branches, one derived from the external iliac artery, the other from the hypogastric artery.

Applied Anatomy.—The inferior epigastric artery has important surgical relations, and is one of the principal means, through its anastomosis with the internal mammary, of establishing the collateral circulation after ligature of either the common or external iliac arteries. It lies close to the abdominal inguinal ring, and is therefore *medial* to an oblique inguinal hernia, but *lateral* to a direct inguinal hernia, as these emerge from the abdomen. It forms the lateral boundary of Hesselbach's triangle, and is in close relationship with the spermatic cord, which lies in front of it in the inguinal canal, separated only by the transversalis fascia. The ductus deferens hooks round its lateral side.

The **deep iliac circumflex artery** arises from the lateral side of the external iliac nearly opposite the inferior epigastric artery. It ascends obliquely behind the inguinal ligament, in a sheath formed by the junction of the transversalis and iliac fasciæ, to the anterior superior iliac spine, where it anastomoses with the ascending branch of the lateral femoral circumflex artery. It then pierces the transversalis fascia and passes along the inner lip of the crest of the ilium to about its middle, where it perforates the Transversus abdominis and runs backwards

* Sir Astley Cooper describes in vol. i. of the *Guy's Hospital Reports* the dissection of a limb eighteen years after successful ligature of the external iliac artery.

between that muscle and the *Obliquus internus*, to anastomose with the iliolumbar and superior gluteal arteries. Opposite the anterior superior iliac spine it gives off a large branch, which ascends between the *Obliquus internus* and *Transversus* muscles, supplying them, and anastomosing with the lumbar and inferior epigastric arteries.

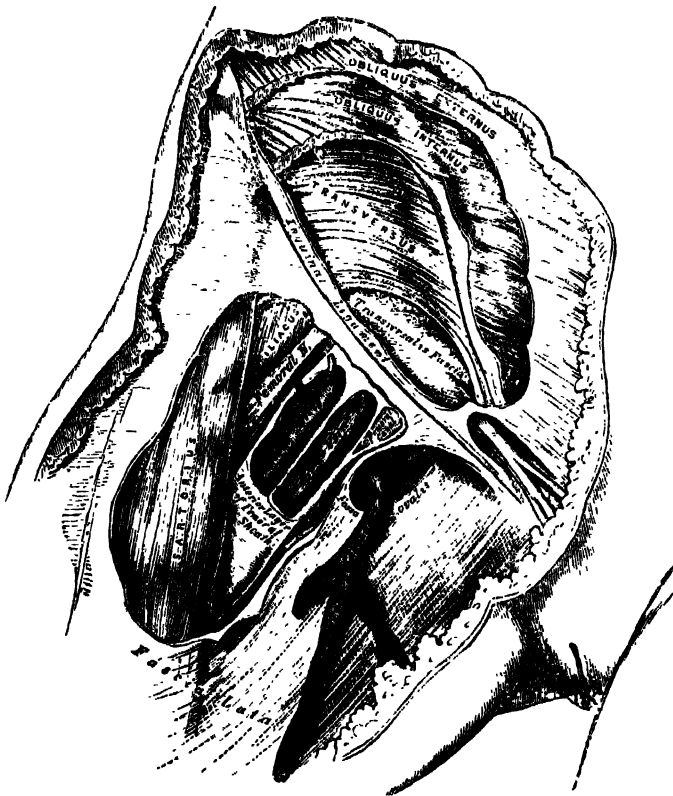
ARTERIES OF THE LOWER EXTREMITY

The chief artery of the lower extremity is a direct continuation of the external iliac. It extends from the level of the inguinal ligament to the lower border of the *Popliteus*, where it divides into the anterior and posterior tibial arteries. Its upper part is named the femoral artery, its lower the popliteal artery.

FEMORAL ARTERY (figs. 655, 656)

The **femoral artery** begins immediately behind the inguinal ligament, midway between the anterior superior spine of the ilium and the symphysis pubis, and passes down the front and medial side of the thigh. It ends at the

FIG. 652. -Femoral sheath laid open to show its three compartments.

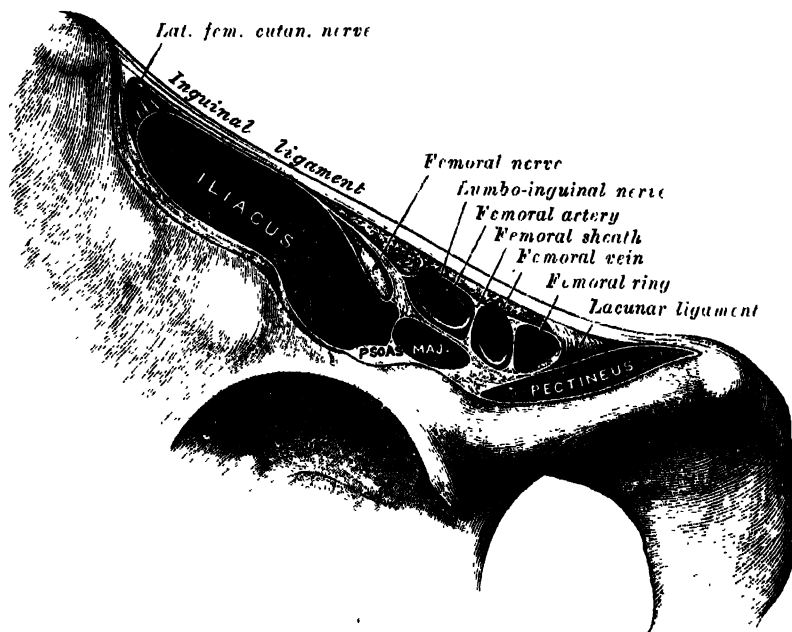


junction of the middle and lower thirds of the thigh where it passes through an opening in the *Adductor magnus* to become the popliteal artery. The first 3 cm. or 4 cm. of the vessel are enclosed, together with the femoral vein, in the *femoral sheath*. The upper part of the femoral artery is contained in the *femoral triangle* (Scarpa's triangle), the lower part in the *adductor canal* (Hunter's canal).

The **femoral sheath** (figs. 652, 653) is formed by a prolongation downwards, behind the inguinal ligament, of the fasciæ which line the abdomen, the

transversalis fascia being continued down in front of the femoral vessels and the iliopectineal fascia behind them. The sheath assumes the form of a short funnel, the wide end of which is directed upwards, while the lower, narrow end fuses with the fascial investment of the vessels, about 3 or 4 cm. below the inguinal ligament. The lateral wall of the sheath is vertical and is perforated by the lumbo-inguinal nerve; the medial wall is directed obliquely downwards and lateralwards, and is pierced by the great saphenous vein and by some lymphatic vessels. The sheath is divided by two vertical partitions which stretch between its anterior and posterior walls. The lateral compartment contains the femoral artery, and the intermediate the femoral vein; the medial and smallest compartment is named the *femoral canal*, and contains some lymphatic vessels and a lymph-gland, imbedded in a small amount of areolar

FIG. 653.—Structures passing behind the inguinal ligament.



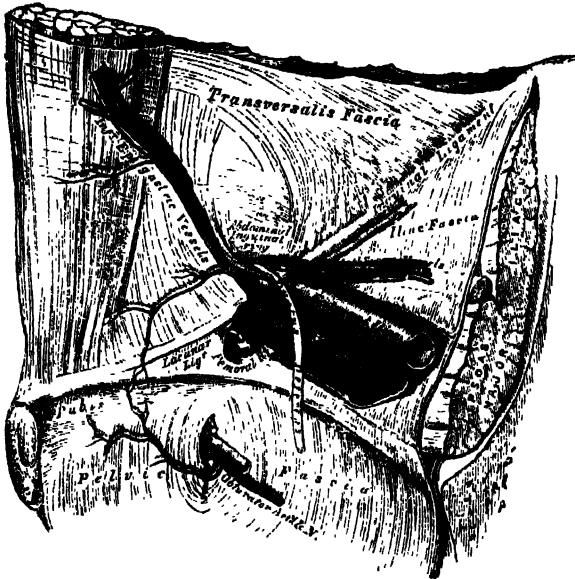
tissue. The femoral canal is conical and measures about 1.25 cm. in length; its base, directed upwards and named the *femoral ring*, is oval in form, its long diameter being directed transversely and measuring about 1.25 cm. The femoral ring (figs. 653, 654) is bounded in front by the inguinal ligament, behind by the Pectineus covered by its fascia, medially by the crescentic base of the lacunar ligament, and laterally by the femoral vein. The spermatic cord in the male, and the round ligament of the uterus in the female, lie immediately above the anterior margin of the ring, while the inferior epigastric vessels are close to its upper and lateral angle. The femoral ring is closed by a somewhat condensed portion of the extraperitoneal connective tissue, named the *septum femorale* (crural septum), the abdominal surface of which supports a small lymph-gland and is covered by the parietal layer of the peritoneum. The septum femorale is pierced by numerous lymphatic vessels passing from the deep inguinal to the external iliac lymph-glands, and the parietal peritoneum immediately above it presents a slight depression named the *femoral fossa*.

The *femoral triangle* (triangle of Scarpa) (fig. 655), corresponds to the depression seen immediately below the fold of the groin. Its apex is directed downwards, and the sides are formed laterally by the medial margin of the Sartorius, medially by the medial margin of the Adductor longus, above by the inguinal ligament. The floor of the triangle is formed from its lateral to its medial side by the Iliacus, Psoas major, Pectineus, and Adductor longus;

and it is divided into two nearly equal parts by the femoral vessels, which extend from near the middle of its base to its apex. On the lateral side of the femoral artery is the femoral nerve dividing into its branches. Besides the vessels and nerves, this triangle contains some fat and lymphatics.

The **adductor canal** (Hunter's canal) is an aponeurotic tunnel in the middle third of the thigh, extending from the apex of the femoral triangle to the opening in the Adductor magnus. It is bounded, in front and laterally, by the Vastus medialis; behind, by the Adductor longus and Adductor magnus; and is covered in by a strong aponeurosis which extends from these muscles, across the femoral vessels, to the Vastus medialis; lying on the aponeurosis is the Sartorius muscle. The canal contains the femoral artery and vein, the saphenous nerve, and the nerve to the Vastus medialis.

FIG. 654.—The relations of the femoral and abdominal inguinal ring seen from within the abdomen. Right side.



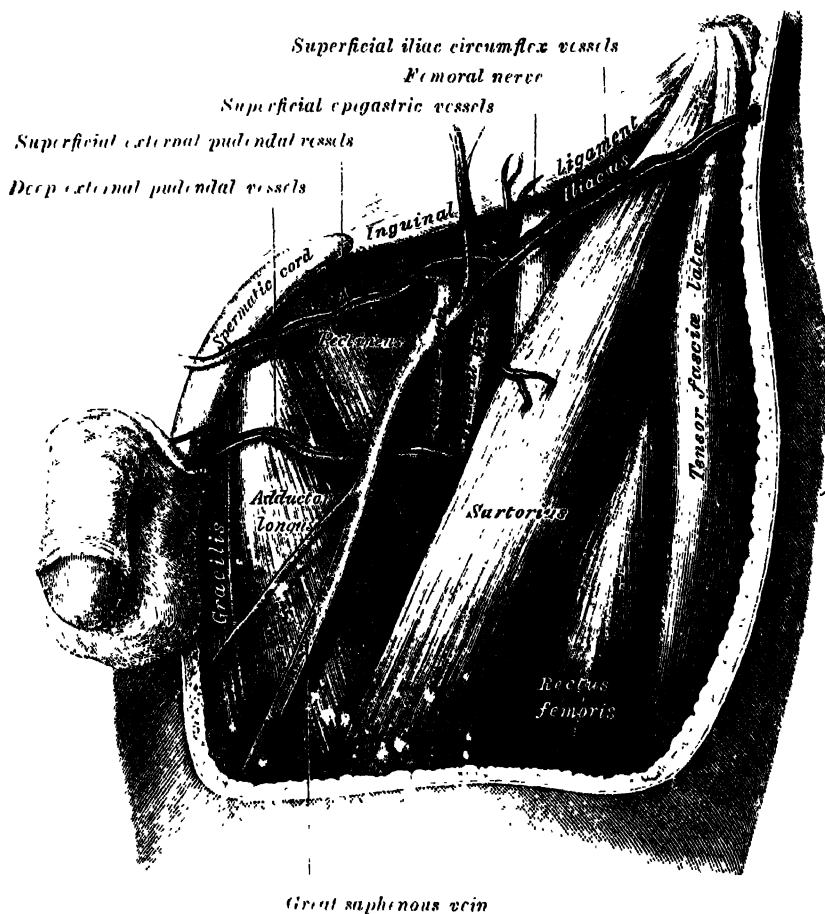
Relations of the femoral artery.—In the *femoral triangle* (fig. 655) the artery is covered by the skin and superficial fascia, the superficial subinguinal lymph-glands, the superficial iliac circumflex vein, the superficial layer of the fascia lata, and the anterior part of the femoral sheath. The lumbo-inguinal nerve courses for a short distance within the lateral compartment of the femoral sheath, and lies at first in front of and then lateral to the artery. Near the apex of the femoral triangle the medial branch of the anterior femoral cutaneous nerve crosses the artery from its lateral to its medial side.

Behind the artery are the posterior part of the femoral sheath, the pectineal fascia, the tendon of the Psoas major, the Pectineus and the Adductor longus. The artery is separated from the capsule of the hip-joint by the tendon of the Psoas major, from the Pectineus by the femoral vein and profunda vessels, and from the Adductor longus by the femoral vein. The nerve to the Pectineus passes medialwards behind the artery. On the *lateral* side of the artery, is the femoral nerve. The femoral vein is medial to the artery in the upper part of the femoral triangle, and posterior to the artery in the lower part.

In the *adductor canal* (fig. 656) the femoral artery is more deeply situated, being covered by the skin, the superficial and deep fasciæ, the Sartorius, and the fibrous roof of the canal; the saphenous nerve crosses it anteriorly from its lateral to its medial side. Behind the artery are the Adductor longus and Adductor magnus; in front and lateral to it is the Vastus medialis. The femoral vein lies posterior to the upper, and lateral to the lower, part of the artery.

Peculiarities.—Several cases are recorded where the femoral artery divided, below the origin of the profunda, into two trunks, which reunited near the opening in the Adductor magnus. A few cases have been reported where the femoral artery was absent, its place being supplied by the inferior gluteal artery which accompanied the sciatic nerve to the popliteal fossa; in these cases the external iliac artery was small, and terminated as the arteria profunda femoris. The femoral vein is occasionally placed along the medial side of the artery throughout the entire extent of the femoral triangle; or it may be duplicated so that a large vein is placed on either side of the artery for a greater or lesser distance.

FIG. 655. —The left femoral triangle.



Applied Anatomy.—Compression of the femoral artery, which is constantly requisite in amputations and other operations on the lower limb, is most effectually made immediately below the inguinal ligament. In this situation the artery is superficial, and is separated from the superior ramus of the os pubis by the Psoas major; here digital compression will effectually control the circulation through it. The vessel may also be controlled in the middle third of the thigh by a tourniquet, which presses the vessel against the medial side of the femur.

The superficial position of the femoral artery in the femoral triangle renders it particularly liable to be injured in wounds, stabs, or gunshot injuries in the groin. On account of the close relationship between the femoral artery and vein, the latter vessel is also liable to be wounded in these injuries. In such cases, the artery having been compressed as it crosses the ramus of the os pubis, the skin wound should be enlarged and the wound in the vessel sought for, and a ligature applied above and below the bleeding point.

Ligature of the femoral artery may be required in cases of wound or aneurysm of the femoral or popliteal arteries or of the arteries of the leg; and the vessel may be exposed and tied in any part of its course. The most favourable situation is at the apex of the femoral triangle. An incision 7 cm. long should be made in the course of the vessel, the

patient lying in the recumbent position, with the limb slightly flexed and abducted, and rotated outwards. A large vein is frequently met with, passing in the course of the artery to join the great saphenous vein, and must be avoided. The fascia lata having been cautiously divided, and the Sartorius displayed, that muscle must be drawn lateralwards in order to expose fully the sheath of the vessels. The finger having been introduced into the wound, and the pulsation of the artery felt, the sheath is opened on the lateral side of the vessel to a sufficient extent to allow of the introduction of the aneurysm needle. In this part of the operation the saphenous nerve and the nerve to the Vastus medialis, which are in close relation with the sheath, should be avoided. The aneurysm needle must be kept close to the artery, to avoid the femoral vein, which lies behind the vessel in this part of its course, and is very closely bound up with it.

To expose the artery in the adductor canal, an incision 7 cm. in length should be made a finger's breadth medial to the line of the artery, the centre of the incision being in the middle of the thigh—i.e. midway between the groin and the knee. The fascia lata having been divided, and the lateral border of the Sartorius exposed, this muscle should be drawn medialwards, when the strong fascia which is stretched across from the Adductors to the Vastus medialis will be observed, and must be freely divided; the sheath of the vessels is now seen, and must be opened, and the artery secured by passing the aneurysm needle between it and the vein, from the lateral to the medial side of the artery. In this situation the femoral vein lies lateral to, and the saphenous nerve in front of the artery.

Collateral Circulation.—After ligation of the femoral artery, the main channels for carrying on the circulation are the following anastomoses:—(1) the superior and inferior gluteal branches of the hypogastric artery with the medial and lateral femoral circumflex and first perforating branches of the arteria profunda femoris; (2) the obturator branch of the hypogastric artery with the medial femoral circumflex of the arteria profunda femoris; (3) the internal pudendal branch of the hypogastric artery with the superficial and deep external pudendal branches of the femoral artery; (4) the deep iliac circumflex branch of the external iliac artery with the lateral femoral circumflex branch of the arteria profunda femoris and the superficial iliac circumflex branch of the femoral artery; and (5) the inferior gluteal branch of the hypogastric artery with the perforating branches of the arteria profunda femoris.

Branches.—The branches of the femoral artery are :

- | | |
|-----------------------------------|----------------------------|
| 1. Superficial epigastric. | 4. Deep external pudendal. |
| 2. Superficial iliac circumflex. | 5. Muscular. |
| 3. Superficial external pudendal. | 6. Profunda femoris. |
| 7. Highest genicular. | |

1. The **superficial epigastric artery** arises from the front of the femoral artery about 1 cm. below the inguinal ligament, and, piercing the femoral sheath and the fascia cribrosa, ascends in front of the inguinal ligament, and between the two layers of the superficial fascia of the abdominal wall nearly as far as the umbilicus. It distributes branches to the superficial subinguinal lymph-glands, the superficial fascia, and the skin; it anastomoses with branches of the inferior epigastric artery, and with its fellow of the opposite side.

2. The **superficial iliac circumflex artery**, the smallest of the superficial branches, arises close to the preceding, and, piercing the fascia lata, runs lateralwards, parallel with the inguinal ligament, as far as the crest of the ilium; it gives branches to the skin, superficial fascia, and superficial subinguinal lymph-glands, and anastomoses with the deep iliac circumflex, the superior gluteal and the lateral femoral circumflex arteries.

3. The **superficial external pudendal artery** arises from the medial side of the femoral artery, close to the preceding vessels, and, after piercing the femoral sheath and fascia cribrosa, courses medialwards, across the spermatic cord (or round ligament of the uterus in the female), to be distributed to the skin on the lower part of the abdomen, the penis and scrotum in the male, and the labium majus in the female, anastomosing with branches of the internal pudendal artery.

4. The **deep external pudendal artery** passes medialwards across the Pectineus and the Adductor longus; it is covered by the fascia lata, which it pierces at the medial side of the thigh, and is distributed, in the male, to the skin of the scrotum and perinæum, in the female to the labium majus; its branches anastomose with the scrotal (or labial) branches of the perinæal artery.

5. **Muscular branches** are supplied by the femoral artery to the Sartorius, Vastus medialis, and Adductores.

6. The *arteria profunda femoris* (fig. 656) is a large vessel arising from the lateral side of the femoral artery, about 3.5 cm. below the inguinal ligament. At first it lies lateral to the femoral artery, and then runs behind it and the femoral vein to the medial side of the femur; it is continued downwards behind the Adductor longus, and ends at the lower third of the thigh in a small branch which pierces the Adductor magnus and anastomoses with the superior muscular branches of the popliteal artery. The terminal part of the profunda is sometimes named the *fourth perforating artery*.

Relations.—*Behind* it, from above downwards, are the Iliacus, Pectineus, Adductor brevis, and Adductor magnus. *In front*, it is separated from the femoral artery by the femoral and profunda veins above, and by the Adductor longus below. *Laterally*, the origin of the Vastus medialis intervenes between it and the femur.

Peculiarities.—This vessel sometimes arises from the medial side, more rarely from the back of the femoral artery. In most cases it arises between 2.25 cm. and 5 cm. below the inguinal ligament; in a few cases the distance is less than 2.25 cm.; more rarely it arises opposite the ligament. Occasionally the distance between the origin of the vessel and the inguinal ligament exceeds 5 cm.

The *arteria profunda femoris* gives off the following branches :

Lateral femoral circumflex.	Perforating.
Medial femoral circumflex.	Muscular.

The **lateral femoral circumflex artery** (external circumflex artery) arises from the lateral side of the profunda, passes lateralwards between the divisions of the femoral nerve and behind the Sartorius and Rectus femoris, and divides into ascending, transverse, and descending branches.

The *ascending branch* passes upwards beneath the Tensor fasciæ latæ to the lateral part of the hip, and anastomoses with the terminal branches of the superior gluteal and deep iliac circumflex arteries.

The *descending branch* runs downwards, behind the Rectus femoris, upon the Vastus lateralis, to which it gives offsets; one long branch descends in the muscle as far as the knee, and anastomoses with the superior lateral genicular branch of the popliteal artery. It is accompanied by the nerve to the Vastus lateralis.

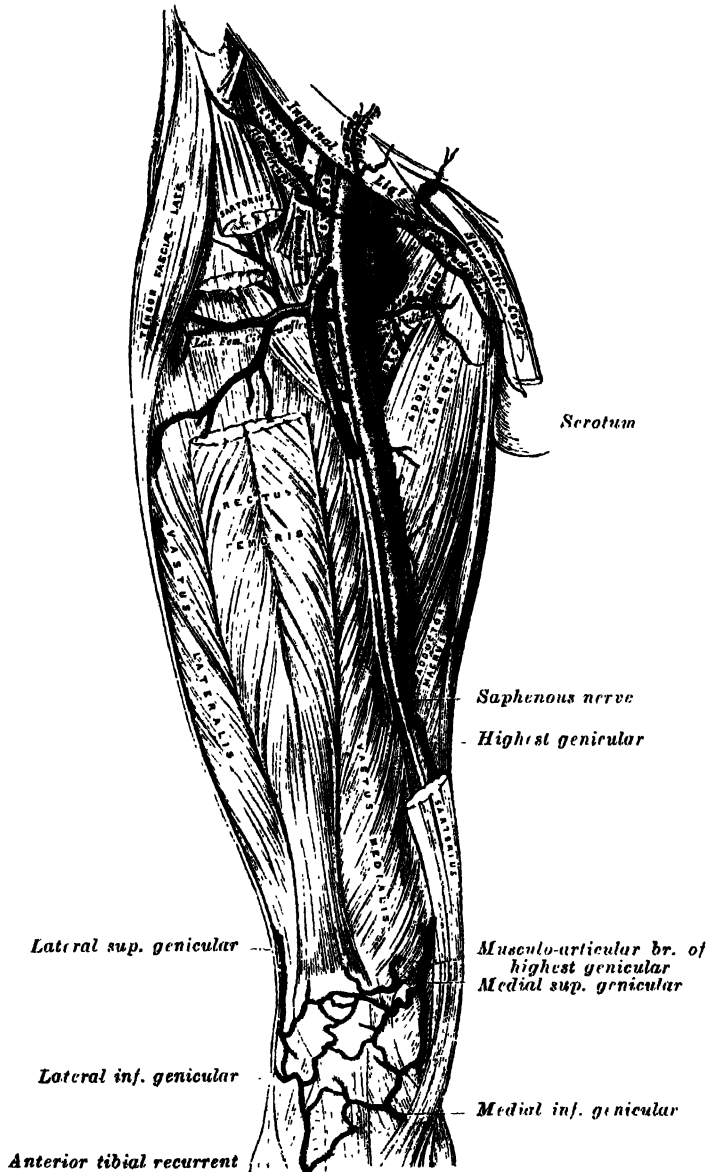
The *transverse branch*, the smallest, passes lateralwards over the Vastus intermedius, pierces the Vastus lateralis, and winds round the femur, just below the greater trochanter, anastomosing on the back of the thigh with the medial femoral circumflex, inferior gluteal, and first perforating arteries.

The **medial femoral circumflex artery** (internal circumflex artery) usually arises from the posteromedial aspect of the profunda, but may spring from the femoral. It winds round the medial side of the femur, passing first between the Pectineus and Psoas major, and then between the Obturator externus and Adductor brevis. At the upper border of the Adductor brevis it gives off two branches; one is distributed to the Adductores, the Gracilis, and Obturator externus, and anastomoses with the obturator artery; the other descends behind the Adductor brevis to supply it and the Adductor magnus; the continuation of the vessel passes backwards and divides into superficial, deep, and acetabular branches. The *superficial branch* appears between the Quadratus femoris and upper border of the Adductor magnus, and anastomoses with the inferior gluteal, lateral femoral circumflex, and first perforating arteries (*crucial anastomosis*). The *deep branch* runs obliquely upwards upon the tendon of the Obturator externus and in front of the Quadratus femoris towards the trochanteric fossa, where it anastomoses with twigs from the gluteal arteries. The *acetabular branch* arises opposite the acetabular notch and enters the hip-joint beneath the transverse acetabular ligament in company with an articular branch from the obturator artery; it supplies the fat in the bottom of the acetabulum, and is continued along the round ligament to the head of the femur.

The **perforating arteries** (fig. 651), usually three in number, are so named because they perforate the insertion of the Adductor magnus to reach the back of the thigh. They pass backwards close to the linea aspera of the femur under cover of small tendinous arches in the muscle. The first is given off above the Adductor brevis, the second in front of that muscle, and the third immediately below it.

The *first perforating artery* passes backwards between the Pectineus and Adductor brevis (sometimes it perforates the latter muscle); it then pierces the Adductor magnus close to the linea aspera. It gives branches to the Adductor brevis,

FIG. 656.—The right femoral artery.



Adductor magnus, Biceps femoris, and Glutæus maximus, and anastomoses with the inferior glutæal, medial and lateral femoral circumflex, and second perforating arteries.

The *second perforating artery*, larger than the first, but frequently arising in common with it, pierces the tendons of the Adductor brevis and Adductor magnus, and divides into ascending and descending branches which supply the posterior femoral muscles, anastomosing with the first and third perforating. The *nutrient*

artery of the femur is usually given off from this artery ; when two nutrient arteries exist, they usually spring from the first and third perforating vessels.

The *third perforating artery* is given off below the Adductor brevis ; it pierces the Adductor magnus and divides into branches which supply the posterior femoral muscles, and anastomose above with the higher perforating arteries, and below with the termination of the profunda and the muscular branches of the popliteal. The nutrient artery of the femur may arise from this branch.

The termination of the profunda artery, already described, is sometimes called the *fourth perforating artery*.

Numerous **muscular branches** arise from the profunda ; some of these end in the Adductores, others pierce the Adductor magnus, give branches to the hamstrings, and anastomose with the medial femoral circumflex artery and with the superior muscular branches of the popliteal.

7. The **highest genicular artery** (*arteria anastomotica magna*) (fig. 656) arises from the femoral just before it passes through the opening in the tendon of the Adductor magnus, and immediately divides into a saphenous and a musculo-articular branch.

The *saphenous branch* pierces the aponeurotic covering of the adductor canal, and accompanies the saphenous nerve to the medial side of the knee. It passes between the Sartorius and Gracilis, and is distributed to the skin of the upper and medial part of the leg, anastomosing with the medial inferior genicular artery.

The *musculo-articular branch* descends in the substance of the Vastus medialis, and in front of the tendon of the Adductor magnus, to the medial side of the knee, where it anastomoses with the medial superior genicular and anterior recurrent tibial arteries. A branch from this vessel crosses above the patellar surface of the femur, forming an anastomotic arch with the lateral superior genicular artery, and supplying branches to the knee-joint.

POPLITEAL FOSSA (fig. 657)

Boundaries.—The popliteal fossa or space is a lozenge-shaped space, at the back of the knee-joint. Laterally it is bounded by the Biceps femoris above, and by the Plantaris and the lateral head of the Gastrocnemius below ; medially it is limited by the Semitendinosus and Semimembranosus above, and by the medial head of the Gastrocnemius below. The floor is formed by the popliteal surface of the femur, the oblique popliteal ligament of the knee-joint, the back of the upper end of the tibia, and the fascia covering the Popliteus ; the fossa is covered in by the fascia lata.

Contents.—The popliteal fossa contains the popliteal vessels, the tibial and the common peroneal nerves, the termination of the small saphenous vein, the lower part of the posterior femoral cutaneous nerve, the articular branch from the obturator nerve, a few small lymph-glands, and a considerable quantity of fat. The tibial nerve descends through the middle of the fossa, lying under the deep fascia, and crossing the vessels posteriorly from the lateral to the medial side. The common peroneal nerve descends on the lateral side of the upper part of the fossa, close to the tendon of the Biceps femoris. On the floor of the fossa are the popliteal vessels, the vein being superficial to the artery and united to it by dense areolar tissue ; the vein is a thick-walled vessel, and lies at first lateral to the artery, and then crosses it posteriorly to gain its medial side below ; sometimes it is double, the artery lying between the two veins, which are usually connected by short transverse branches. The articular branch from the obturator nerve descends upon the artery to the knee-joint. The popliteal lymph-glands, six or seven in number, are imbedded in the fat ; one lies beneath the popliteal fascia near the termination of the external saphenous vein, another between the popliteal artery and the back of the knee-joint, while the others are placed at the sides of the popliteal vessels.

POPLITEAL ARTERY (fig. 657)

The **popliteal artery** is the continuation of the femoral artery, and courses through the popliteal fossa. It extends from the opening in the Adductor magnus, at the junction of the middle with the lower third of the thigh, downwards and laterally to the intercondyloid fossa of the femur, and then vertically downwards to the lower border of the Popliteus, where it divides into *anterior* and *posterior tibial arteries*.

Relations.—In *front* of the artery, from above downwards, are the popliteal surface of the femur (separated from the vessel by some fat), the back of the knee-joint, and the fascia covering the Popliteus. *Behind*, it is overlapped by the Semimembranosus above, and is covered by the Gastrocnemius and Plantaris below. In the middle part of its course the artery is separated from the skin and fasciæ by a quantity of fat, and is crossed from the lateral to the medial side by the tibial nerve and the popliteal vein, the vein being between the nerve and the artery and closely adherent to the latter. On its *lateral side*, above, are the Biceps femoris, the tibial nerve, the popliteal vein, and the lateral condyle of the femur; below, the Plantaris and the lateral head of the Gastrocnemius. On its *medial side*, above, are the Semimembranosus and the medial condyle of the femur; below, the tibial nerve, the popliteal vein, and the medial head of the Gastrocnemius. The relations of the popliteal lymph-glands to the artery are described on the previous page.

Peculiarities.—Occasionally the popliteal artery divides into its terminal branches opposite the knee-joint; when this occurs the anterior tibial artery usually descends in front of the Popliteus. The popliteal artery sometimes divides into the anterior tibial and peroneal arteries, the posterior tibial artery being wanting, or rudimentary; occasionally it divides into three branches, the anterior and posterior tibial, and peroneal arteries.

Applied Anatomy.—The popliteal artery is not infrequently the seat of injury. It may be torn by direct violence, as by the passage of a cart-wheel over the knee, or by hyperextension of the knee. It may also be lacerated by fracture of the lower part of the femur, or by anteroposterior dislocation of the knee-joint. It has been torn in breaking down adhesions in cases of fibrous ankylosis of the knee, and is in danger of being wounded in performing Macewen's operation of osteotomy of the lower end of the femur for genu valgum. It is more frequently the seat of aneurysm than any other artery except the thoracic aorta. No doubt this is due in a great measure to the amount of movement to which it is subjected, and to the fact that it is supported by loose and lax tissue only, and not by muscles, as is the case with most arteries. When the knee is acutely flexed, the popliteal artery becomes bent on itself to such an extent as entirely to arrest the circulation through it.

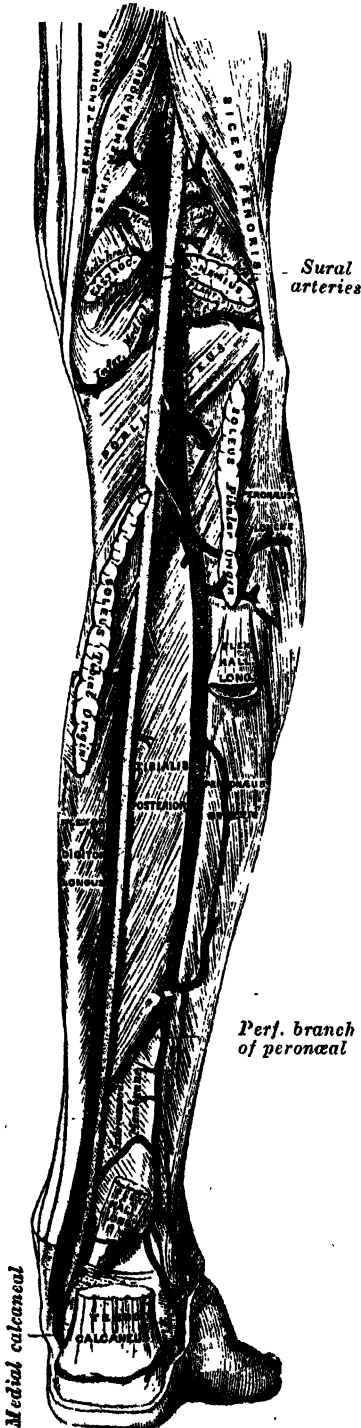
Ligature of the popliteal artery is required in cases of wound of the vessel, but for aneurysm it is preferable to tie the femoral. The popliteal may be tied in the upper or lower part of its course; in the middle of the popliteal fossa the operation is attended with considerable difficulty, from the great depth of the vessel, and from the extreme degree of tension of the lateral and medial boundaries of the fossa.

In order to expose the upper part of the vessel, the patient should be placed in the supine position, with the knee flexed and the thigh abducted and rotated outwards so that it rests on its lateral surface; an incision 7 cm. or 8 cm. in length, beginning at the junction of the middle with the lower third of the thigh, is to be made parallel to and immediately behind the tendon of the Adductor magnus, and the skin, superficial and deep fasciæ divided. The tendon of the muscle is thus exposed, and is to be drawn forwards, and the hamstring tendons backwards. A quantity of fatty tissue will now be opened up, in which the artery will be felt pulsating. This tissue is to be separated with the point of a director until the artery is exposed. The vein and nerve will not be seen, as they lie to the lateral side of the artery. The sheath is to be opened, and the aneurysm needle passed from before backwards, keeping its point close to the artery for fear of injuring the vein. The only structure to avoid in the superficial incision is the great saphenous vein.

To expose the vessel in the lower part of its course, where it lies between the two heads of the Gastrocnemius, the patient should be placed in the prone position with the limb extended. An incision should then be made through the skin in the middle line, commencing opposite the bend of the knee-joint, care being taken to avoid the small saphenous vein and the medial sural cutaneous nerve. After dividing the deep fascia, and separating some dense cellular tissue, the artery, vein, and nerve will be exposed between the two heads of the Gastrocnemius. Some muscular branches of the artery should be avoided if possible, or, if divided, tied immediately. The leg being now flexed,

in order the more effectually to separate the two heads of the Gastrocnemius, the nerve should be drawn medialwards and the vein lateralwards, and the aneurysm needle passed between the artery and vein from the lateral to the medial side.

FIG. 657.—The popliteal, posterior tibial, and peroneal arteries.



Branches.—The branches of the popliteal artery are :

Cutaneous.

Muscular

Genicular

{ Superior.
 { Sural.
 { Medial superior.
 { Lateral superior.
 { Middle.
 { Medial inferior.
 { Lateral inferior.

The **cutaneous branches** arise either from the popliteal artery or from some of its branches; they descend between the two heads of the Gastrocnemius, and, piercing the deep fascia, are distributed to the skin of the back of the leg; one usually accompanies the small saphenous vein.

The **superior muscular branches**, two or three in number, arise from the upper part of the artery, and pass to the Adductor magnus and the hamstring muscles, anastomosing with the terminal part of the arteria profunda femoris.

The **sural arteries** are two large branches which arise opposite the knee-joint and are distributed to the Gastrocnemius, Soleus, and Plantaris.

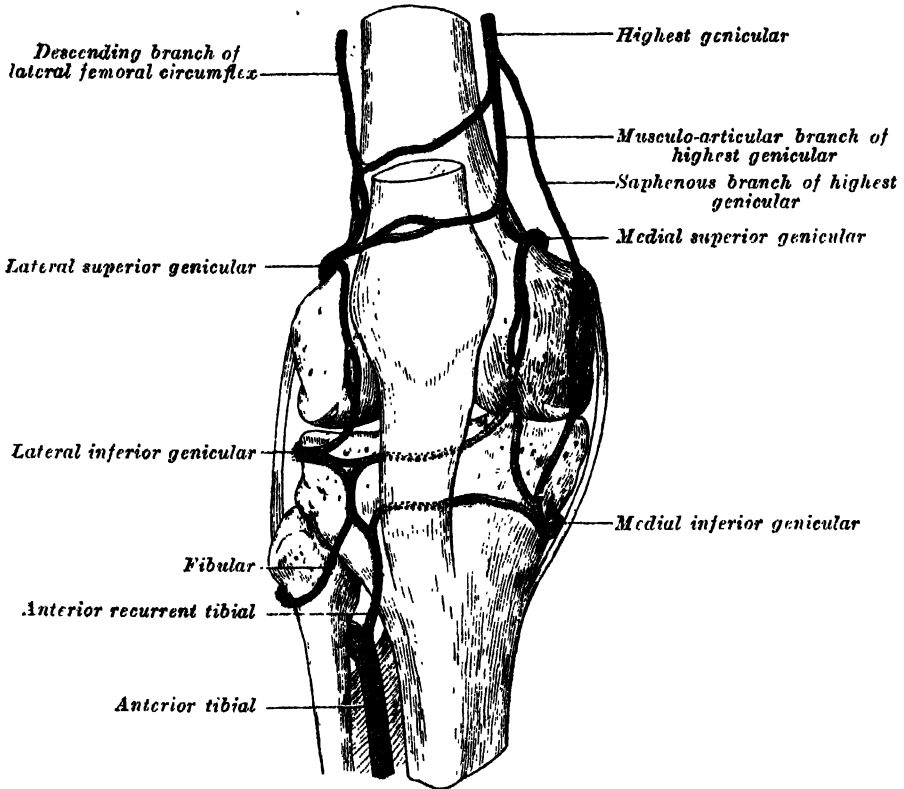
The **superior genicular arteries** (superior articular arteries) (figs. 657, 658), two in number, arise one on either side of the popliteal artery, and wind round the femur immediately above its condyles to the front of the knee-joint. The **medial superior genicular artery** runs in front of the Semimembranosus and Semitendinosus, above the medial head of the Gastrocnemius, and passes beneath the tendon of the Adductor magnus. It divides into two branches, one of which supplies the Vastus medialis and anastomoses with the highest genicular and medial inferior genicular arteries; the other ramifies close to the surface of the femur, and anastomoses with the lateral superior genicular artery. The size of the medial superior genicular artery varies inversely with that of the highest genicular. The **lateral superior genicular artery** passes beneath the tendon of the Biceps femoris, and divides into a superficial and a deep branch; the superficial branch supplies the Vastus lateralis, and anastomoses with the descending branch of the lateral femoral circumflex artery and with the lateral inferior genicular artery; the deep branch anastomoses with the medial inferior

genicular artery, and forms an arch across the front of the bone with the highest genicular artery.

The **middle genicular artery** (azygos articular artery), a small branch, arises from the popliteal artery opposite the back of the knee-joint; it pierces the oblique popliteal ligament, and supplies the cruciate ligaments and the synovial stratum of the articular capsule.

The **inferior genicular arteries** (inferior articular arteries) (figs. 657, 658), two in number, arise from the popliteal artery beneath the Gastrocnemius. The **medial inferior genicular artery** descends along the upper margin of the Popliteus, to which it gives branches; it then passes below the medial condyle of the tibia and beneath

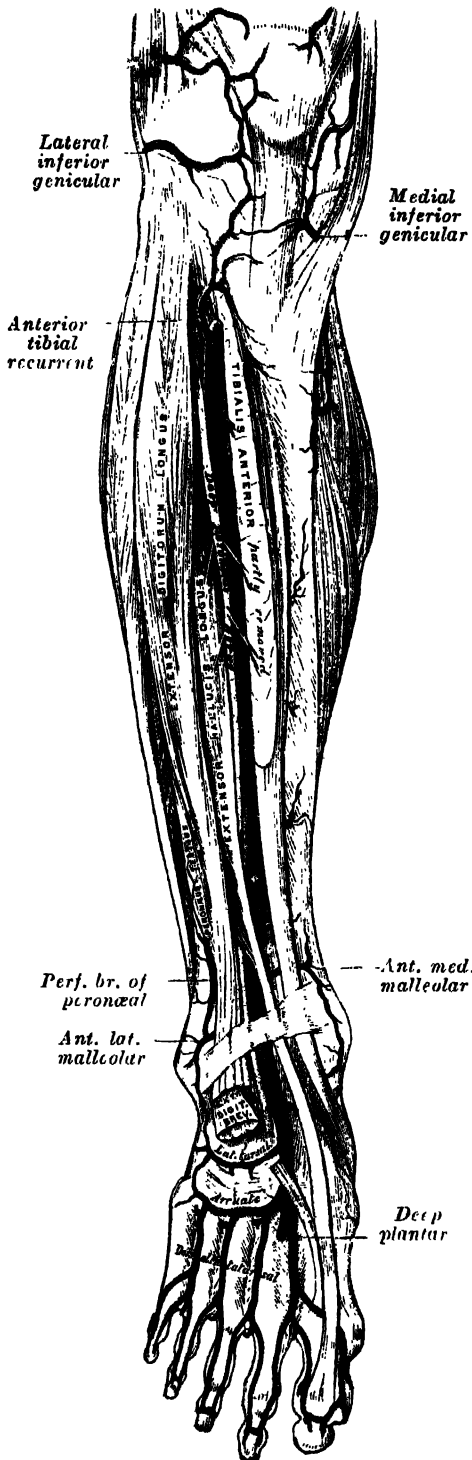
FIG. 658.—Anastomosis around the knee-joint.



the tibial collateral ligament; at the anterior border of this ligament it ascends to the front and medial side of the joint, supplies the joint and the upper end of the tibia and anastomoses with the lateral inferior and medial superior genicular arteries. The **lateral inferior genicular artery** runs lateralwards above the head of the fibula to the front of the knee-joint, passing in its course beneath the lateral head of the Gastrocnemius, the fibular collateral ligament, and the tendon of the Biceps femoris. It divides into branches which anastomose with the medial inferior genicular, lateral superior genicular, and anterior recurrent tibial arteries.

The **anastomosis around the knee-joint** (fig. 658).—Around and above the patella, and on the contiguous ends of the femur and tibia, is an intricate arterial anastomosis forming a superficial and a deep network. The **superficial network** is situated between the fascia and skin round about the patella, and forms three well-defined arches; one above the patella in the loose connective tissue over the Quadriceps femoris, and two below the patella in the fat behind the ligamentum patellæ. The **deep network** lies on the lower end of the femur and upper end of the tibia around their articular surfaces, and sends numerous offsets into the interior of the joint. The arteries which form the anastomosis are the two medial and the two lateral genicular branches of the popliteal, the highest genicular, the descending branch of

FIG. 659.—Anterior tibial and dorsalis pedis arteries.



the lateral femoral circumflex, the fibular, and the anterior recurrent tibial.

ANTERIOR TIBIAL ARTERY (fig. 659)

The anterior tibial artery begins at the bifurcation of the popliteal artery, at the lower border of the Popliteus, passes forwards between the two heads of the Tibialis posterior and through the upper part of the crural interosseous membrane, to the front of the leg: it here lies close to the medial side of the neck of the fibula. It descends on the anterior surface of the crural interosseous membrane, gradually approaching the tibia: at the lower part of the leg it lies on this bone, and then on the front of the ankle-joint midway between the two malleoli, where it becomes the *dorsalis pedis* artery.

Relations.—In the upper two-thirds of its extent, the anterior tibial artery rests upon the crural interosseous membrane; in the lower third, upon the front of the tibia and the anterior ligament of the ankle-joint. In the upper third of its course, it lies between the Tibialis anterior and Extensor digitorum longus; in the middle third between the Tibialis anterior and Extensor hallucis longus. At the ankle it is crossed from the lateral to the medial side by the tendon of the Extensor hallucis longus, and lies between it and the first tendon of the Extensor digitorum longus. Its upper two-thirds are covered by the muscles which lie on either side of it, and by the deep fascia; its lower third, by the skin and fascia, and the transverse and cruciate crural ligaments.

A pair of *venæ comitantes* lie one on either side of the artery. The deep peroneal nerve, coursing round the lateral side of the neck of the fibula, comes into relation with the lateral side of the artery shortly after it has reached the front of the leg; about the middle of the leg the nerve is in front of the artery; at the lower part it is generally on the lateral side again.

Peculiarities.—This vessel may be smaller than usual, or may be absent, its place being supplied by perforating branches from the posterior tibial, or by the perforating branch of the peroneal artery. The artery occasionally deviates towards the fibular side of the leg, regaining its usual

position at the front of the ankle. Very occasionally it approaches the surface at the leg, and is covered merely by the skin and fascia below that point.

Applied Anatomy.—The anterior tibial artery is liable to be injured in fractures of the lower third of the tibia, on account of its close proximity to the bone. The application of a ligature to the vessel is rarely required, except in cases of wound or traumatic aneurysm. The operation in the upper half of the leg is difficult on account of the depth of the vessel from the surface. An incision about 10 cm. in length is made 3 cm. lateral to the anterior border of the tibia. The skin and superficial structures having been divided and the deep fascia exposed, the white line separating the Tibialis anterior from the Extensor digitorum longus is sought. When this has been clearly defined, the deep fascia is to be divided in this line, and the Tibialis anterior separated from adjacent muscles until the interosseous membrane is reached. The foot is to be flexed in order to relax the muscles, and upon drawing them apart the artery will be found lying on the interosseous membrane with the nerve lateral or superficial to it. The nerve should be drawn lateralwards, the venæ comitantes separated from the artery and the needle passed around it.

To tie the vessel in the lower third of the leg, an incision about 7 cm. in length should be made through the skin between the tendons of the Tibialis anterior and Extensor hallucis longus, the deep fascia being divided to the same extent. The tendon on either side should be retracted, when the vessel, accompanied by the venæ comitantes, will be seen lying upon the tibia, with the nerve on the lateral side.

Branches.—The branches of the anterior tibial artery are :

Posterior tibial recurrent.	Anterior medial malleolar.
Anterior tibial recurrent.	Anterior lateral malleolar.
Muscular.	

The **posterior tibial recurrent artery**, an inconstant branch, is given off from the anterior tibial artery before that vessel reaches the front of the leg. It ascends in front of the Popliteus, anastomoses with the inferior genicular branches of the popliteal artery, and gives an offset to the tibiofibular joint.

The **anterior tibial recurrent artery** arises from the anterior tibial artery, as soon as that vessel has reached the front of the limb; it ascends in the Tibialis anterior, ramifies on the front and sides of the knee-joint, and assists in the formation of the patellar network by anastomosing with the genicular branches of the popliteal artery, and with the highest genicular artery.

The **muscular branches** are numerous and are distributed to the muscles which lie on either side of the vessel; some pierce the deep fascia to supply the skin, others pass through the crural interosseous membrane, and anastomose with branches of the posterior tibial and peronæal arteries.

The **anterior medial malleolar artery** (internal malleolar artery) arises about 5 cm. above the ankle-joint, and passes behind the tendons of the Extensor hallucis longus and Tibialis anterior, to the medial side of the ankle, where it anastomoses with branches of the posterior tibial and medial plantar arteries.

The **anterior lateral malleolar artery** (external malleolar artery) passes beneath the tendons of the Extensor digitorum longus and Peronæus tertius; it supplies the lateral side of the ankle and anastomoses with the perforating branch of the peronæal artery and with ascending twigs from the lateral tarsal artery.

The arteries around the ankle-joint anastomose freely with one another and form networks below the corresponding malleoli. The *medial malleolar network* is formed by the anterior medial malleolar branch of the anterior tibial artery, the medial tarsal branches of the dorsalis pedis artery, the posterior medial malleolar and medial calcaneal branches of the posterior tibial artery, and branches from the medial plantar artery. The *lateral malleolar network* is formed by the anterior lateral malleolar branch of the anterior tibial artery, the lateral tarsal branch of the dorsalis pedis artery, the perforating and the lateral calcaneal branches of the peronæal artery, and twigs from the lateral plantar artery.

ARTERIA DORSALIS PEDIS (fig. 659)

The **arteria dorsalis pedis**, the continuation of the anterior tibial artery, passes forwards from the ankle-joint along the tibial side of the dorsum of the foot to the proximal part of the first intermetatarsal space, where it divides into the *first dorsal metatarsal* and the *deep plantar arteries*.

Relations.—The *arteria dorsalis pedis* is accompanied by two veins, and lies successively upon the front of the articular capsule of the ankle-joint, the talus, navicular, and second cuneiform bones, and the ligaments connecting them. It is covered by the skin, fascia, and cruciate crural ligament, and crossed near its termination by the first tendon of the *Extensor digitorum brevis*. On its *tibial side* is the tendon of the *Extensor hallucis longus*; on its *fibular side*, the first tendon of the *Extensor digitorum longus*, and the termination of the deep peroneal nerve.

Peculiarities.—The *arteria dorsalis pedis* may be larger than usual, to compensate for a deficient plantar artery; its branches to the toes may be absent, the toes then being supplied by the medial plantar; or its place may be taken altogether by a large perforating branch of the peroneal artery. It frequently curves lateralwards, lying lateral to the line between the middle of the ankle and the proximal part of the first interosseous space.

Applied Anatomy.—The *arteria dorsalis pedis* may be tied, by making an incision 5 cm. in length, through the skin on the fibular side of the tendon of the *Extensor hallucis longus*, in the interval between it and the medial border of the *Extensor digitorum brevis*. The incision should not extend farther forwards than the proximal part of the first intermetatarsal space, as the artery divides in that situation. When the deep fascia has been divided the artery will be exposed, with the deep peroneal nerve lying lateral to it.

Branches.—The branches of the *arteria dorsalis pedis* are :

Lateral tarsal.
Medial tarsal.

Arcuate.
First dorsal metatarsal.

Deep plantar.

The **lateral tarsal artery** arises from the *arteria dorsalis pedis* as the latter crosses the navicular bone; it passes lateralwards and forms an arch upon the tarsal bones, being covered by the *Extensor digitorum brevis*; it supplies this muscle and the articulations of the tarsus, and anastomoses with branches of the arcuate, anterior lateral malleolar, and lateral plantar arteries, and with the perforating branch of the peroneal artery.

The **medial tarsal arteries** are two or three small branches; they ramify on the medial border of the foot and join the medial malleolar network.

The **arcuate artery** (metatarsal artery) arises a little anterior to the lateral tarsal artery; it passes lateralwards over the bases of the metatarsal bones beneath the tendons of the *Extensor digitorum brevis*, and anastomoses with the lateral tarsal and lateral plantar arteries. It gives off the *second, third, and fourth dorsal metatarsal arteries*, which run forwards upon the corresponding *Interossei dorsales*; in the clefts between the toes each divides into two dorsal digital branches for the adjoining toes. At the proximal parts of the interosseous spaces the dorsal metatarsal arteries receive the posterior perforating branches from the plantar arch, and at the distal parts of the spaces they are joined by the anterior perforating branches from the plantar metatarsal arteries. The fourth dorsal metatarsal artery gives off a branch which supplies the lateral side of the fifth toe.

The **first dorsal metatarsal artery** (*arteria dorsalis hallucis*) runs forward on the first *Interosseus dorsalis*, and at the cleft between the first and second toes divides into two branches, one of which passes beneath the tendon of the *Extensor hallucis longus*, and is distributed to the medial border of the great toe; the other bifurcates to supply the adjoining sides of the great and second toes.

The **deep plantar artery** (communicating artery) descends into the sole of the foot, between the two heads of the first *Interosseus dorsalis*, and completes the plantar arch by uniting with the termination of the lateral plantar artery. At its junction with the lateral plantar artery it gives off the *first plantar metatarsal artery* (p. 669).

POSTERIOR TIBIAL ARTERY (fig. 657)

The **posterior tibial artery** begins at the lower border of the *Popliteus*, opposite the interval between the tibia and fibula, and passes downwards and medialwards on the back of the leg. In the lower part of its course it is situated midway between the medial malleolus and the medial process of the calcaneal tuberosity. It divides beneath the origin of the *Abductor hallucis* into the *medial and lateral plantar arteries*.

Relations.—The posterior tibial artery lies successively upon the Tibialis posterior, the Flexor digitorum longus, the tibia, and the back of the ankle-joint. Its uppermost part is covered by the Gastrocnemius and Soleus and the deep transverse fascia of the leg, its terminal part by the Abductor hallucis. In the lower third of the leg, it is more superficial, and is covered only by the skin and fascia, and runs parallel with the medial border of the tendo calcaneus. It is accompanied by two veins, and by the tibial nerve which lies at first to its medial side, but soon crosses it posteriorly, and is, in the greater part of its course, on its lateral side.

Behind the medial malleolus, the structures which pass under cover of the laciniated ligament are arranged in the following order from the medial to the lateral side; first, the tendons of the Tibialis posterior and Flexor digitorum longus lying in the same groove behind the malleolus, the former being the more medial; then the posterior tibial artery, with a vein on either side of it; lateral to the tibial vessels is the tibial nerve; and about 1.25 cm. nearer the heel is the tendon of the Flexor hallucis longus.

Peculiarities.—The posterior tibial artery may be small or absent, its place being supplied by a large peroneal artery, which either joins the small posterior tibial artery, or continues alone to the sole of the foot.

Applied Anatomy.—Ligature of the posterior tibial artery may be required in cases of wound of the sole of the foot, attended with great hemorrhage; the vessel should then be tied at the ankle. In cases of wound of the posterior tibial, it will be necessary to enlarge the opening so as to expose the vessel at the wounded point, excepting where the vessel is injured by a punctured wound from the front of the leg. In cases of aneurysm from wound of the artery low down, the vessel should be tied in the middle of the leg.

To tie the posterior tibial artery at the ankle, a curved incision, about 6 cm. long, and with its convexity directed backwards, should be made through the skin, midway between the heel and the medial malleolus, or a little nearer the latter. The subcutaneous tissue having been divided, the laciniated (internal annular) ligament is seen. This is divided, and the sheath of the vessels exposed and opened, when the artery is seen with one of the venæ comitantes on either side. The aneurysm needle should be passed round the vessel from the heel towards the ankle, in order to avoid the tibial nerve, care at the same time being taken not to include the venæ comitantes.

The vessel may also be tied in the lower third of the leg by making an incision about 8 cm. long, parallel with the medial border of the tendo calcaneus. The great saphenous vein must be avoided, and the two layers of fascia divided upon a director, when the artery is exposed along the lateral margin of the Flexor digitorum longus, with one of its venæ comitantes on either side, and the nerve lying lateral to it.

Ligature of the posterior tibial in the middle of the leg is a very difficult operation, on account of the great depth of the vessel from the surface. The patient being placed in the recumbent position, the injured limb should rest on its fibular side, the knee being partially bent, and the foot extended, so as to relax the muscles of the calf. An incision about 10 cm. in length should then be made through the skin, a finger's breadth behind the medial margin of the tibia, care being taken to avoid the great saphenous vein. The deep fascia having been divided, the margin of the Gastrocnemius is exposed, and drawn aside, and the tibial attachment of the Soleus divided. The artery may now be felt pulsating beneath the deep transverse fascia, about 2.5 cm. from the margin of the tibia. This fascia having been divided, and the limb placed in such a position as will relax the muscles of the calf as much as possible, the veins should be separated from the artery and the aneurysm needle passed round the vessel from the lateral to the medial side, so as to avoid wounding the tibial nerve.

Branches.—The branches of the posterior tibial artery are:

- | | |
|-------------------|--------------------------------|
| 1. Fibular. | 6. Posterior medial malleolar. |
| 2. Peroneal. | 7. Medial calcaneal. |
| 3. Nutrient. | 8. Medial plantar. |
| 4. Muscular. | 9. Lateral plantar. |
| 5. Communicating. | |

1. The **fibular artery**, sometimes a branch of the anterior tibial artery, passes lateralwards round the neck of the fibula, through the Soleus, and anastomoses with lateral inferior genicular artery.

2. The **peroneal artery** arises from the posterior tibial, about 2.5 cm. below the lower border of the Popliteus. It passes obliquely towards the fibula, and descends along the medial side of that bone, contained in a fibrous canal between the Tibialis posterior and the Flexor hallucis longus, or in the substance of the

latter muscle. It then runs behind the inferior tibiofibular joint, and divides into lateral calcaneal branches which ramify on the lateral and posterior surfaces of the calcaneus.

It is covered, in the *upper* part of its course, by the Soleus and deep transverse fascia of the leg; in the *lower* part, by the Flexor hallucis longus.

Peculiarities.—The peronæal artery may arise 7 or 8 cm. below the Popliteus, or from the posterior tibial high up, or even from the popliteal. It is more frequently increased than diminished in size; and then it either joins and reinforces the posterior tibial artery, or takes the place of that artery in the lower part of the leg and foot. When the peronæal artery is smaller than usual, a branch from the posterior tibial artery supplies its place; and a branch from the anterior tibial artery compensates for the diminished perforating artery.

The peronæal artery gives off the following branches:

Muscular branches are supplied to the Soleus, Tibialis posterior, Flexor hallucis longus, and Peronæi.

A *nutrient artery* supplies the fibula, and is directed downwards.

A *perforating branch* pierces the crural interosseous membrane, about 5 cm. above the lateral malleolus, and reaches the front of the leg, where it anastomoses with the anterior lateral malleolar; it then passes down in front of the inferior tibiofibular joint, gives branches to the tarsus, and anastomoses with the lateral tarsal artery. The perforating branch is sometimes enlarged, and may take the place of the dorsalis pedis artery.

A *communicating branch* arises from the peronæal artery about 5 cm. above the lower end of the tibia, and joins the communicating branch of the posterior tibial artery.

Lateral calcaneal or terminal branches of the peronæal artery pass to the lateral side of the heel, and communicate with the anterior lateral malleolar artery and, on the back of the heel, with the medial calcaneal arteries.

3. The **nutrient artery** of the tibia arises from the posterior tibial artery near its origin, and, after supplying a few minute muscular branches, enters the nutrient canal in the bone; this canal is situated immediately below the popliteal line and is directed downwards.

4. **Muscular branches** are distributed to the Soleus and to the deep muscles on the back of the leg.

5. The **communicating branch** runs transversely across the back of the tibia about 5 cm. above its lower end, beneath the Flexor hallucis longus, and joins the communicating branch of the peronæal artery.

6. The **posterior medial malleolar artery** is a small branch which winds round the tibial malleolus and ends in the media' malleolar network.

7. The **medial calcaneal branches** are several large arteries which arise from the posterior tibial just before its division; they pierce the lacinate ligament and are distributed to the fat and skin behind the tendo calcaneus and about the heel, and to the muscles on the tibial side of the sole, anastomosing with the peronæal and medial malleolar arteries, and, on the back of the heel, with the lateral calcaneal arteries.

8. The **medial plantar artery** (internal plantar artery) (figs. 660, 661), the smaller of the terminal branches of the posterior tibial artery, passes forwards along the medial side of the foot. It is at first situated above the Abductor hallucis, and then between it and the Flexor digitorum brevis, both of which it supplies. At the base of the first metatarsal bone, where it is much diminished in size, it passes along the medial border of the first toe and anastomoses with the first dorsal metatarsal artery. Three small superficial digital branches accompany the digital branches of the medial plantar nerve and join the first, second and third plantar metatarsal arteries.

9. The **lateral plantar artery** (external plantar artery) (fig. 661), the larger of the terminal branches of the posterior tibial artery, passes at first obliquely lateralwards and forwards to the base of the fifth metatarsal bone in company with the lateral plantar nerve. It then turns medialwards with the deep branch of the nerve, to the interval between the bases of the first and second metatarsal bones, where it unites with the deep plantar branch of the dorsalis pedis artery, thus completing the *plantar arch*. As this artery passes lateralwards, it is first placed between the calcaneus and Abductor hallucis, and then between the Flexor digitorum brevis and Quadratus plantæ; as it runs forwards to the base of the fifth metatarsal bone it lies between the Flexor digitorum brevis and Abductor digiti quinti, and is covered by the plantar aponeurosis superficial fascia and skin. The remainder of the vessel is deeply situated; it extends from the base of the fifth metatarsal bone to

the proximal part of the first interosseous space, and forms the plantar arch ; it is convex forwards, lies below the bases of the second, third, and fourth metatarsal bones and the corresponding Interossei and upon the oblique part of the Adductor hallucis.

Branches.—The plantar arch distributes numerous twigs to the skin, fasciæ and muscles in the sole, and gives off the following branches :

(a) **Perforating branches**, three in number, ascend through the proximal part of the second, third, and fourth interosseous spaces, between the heads of the Interossei dorsales, and anastomose with the dorsal metatarsal arteries.

FIG. 660.—The plantar arteries.
Superficial view.

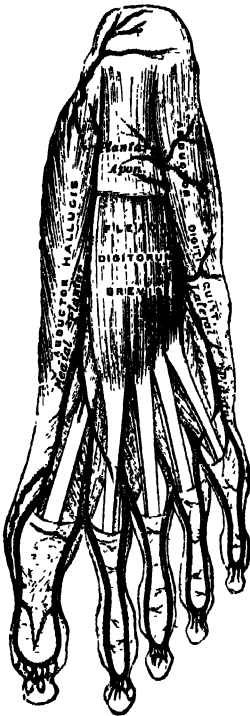


FIG. 661.—The plantar arteries.
Deep view.



(b) **Plantar metatarsal arteries** (fig. 661), four in number, run forwards between the metatarsal bones and in contact with the Interossei. Each divides into a pair of plantar digital arteries which supply the adjacent sides of the toes. Near their points of division each sends upwards an *anterior perforating branch* to join the corresponding dorsal metatarsal artery. The first plantar metatarsal artery (*arteria magna hallucis*) springs from the junction between the lateral and deep plantar arteries (p. 666), and sends a digital branch to the medial side of the first toe. The digital branch for the lateral side of the fifth toe arises from the lateral plantar artery near the base of the fifth metatarsal bone.

Applied Anatomy.—Wounds of the plantar arch are always serious, on account of the depth of the vessel and the important structures which must be interfered with in an attempt to ligature it. They must be treated on similar lines to those of wounds of the volar arches (p. 627). Pressure locally, combined with elevation of the limb, may in some cases be sufficient to arrest the bleeding, but if this fails, an attempt should be made to find the bleeding point and ligature it. Should this prove unsuccessful, it may be necessary to ligature the femoral artery below the origin of the *arteria profunda femoris*, as ligature of the anterior and posterior tibial arteries may not be sufficient to control the hæmorrhage, and it is safer and quicker to tie the femoral under the circumstances.

THE VEINS

The veins convey the blood from the capillaries of the different parts of the body to the heart. They consist of two sets, *pulmonary* and *systemic*.

The **pulmonary veins**, unlike other veins, contain arterial blood, which they return from the lungs to the left atrium of the heart.

The **systemic veins** return the venous blood from the body generally, to the right atrium of the heart.

The **portal vein**, an appendage to the systemic venous system, is confined to the abdominal cavity, and conveys the venous blood from the spleen and the viscera of digestion to the liver, where it breaks up into a network of capillary-like vessels, from which the blood is drained by the hepatic veins to the inferior vena cava.

The veins receive the blood from the capillaries, and unite with one another to form larger vessels which, in their passage towards the heart, increase in size as they receive tributaries, or join other veins. The veins are larger and more numerous than the arteries; hence, the capacity of the veins is greater than that of the arteries; the capacity of the pulmonary veins, however, only slightly exceeds that of the pulmonary arteries. The veins are cylindrical like the arteries; their walls, however, are thin and they collapse when the vessels are empty, and the uniformity of their surfaces is interrupted at intervals by slight constrictions, which indicate the existence of valves in their interior (p. 550). They communicate very freely with one another, especially in certain regions of the body. Thus, between the venous sinuses of the cranium, and between the veins of the neck, where obstruction would be attended with imminent danger to the cerebral circulation, large and frequent anastomoses are found. Free communications also exist between the veins of the vertebral canal, and between the veins composing the various venous plexuses in the abdomen and pelvis.

The systemic venous channels are subdivided into three sets, viz. superficial and deep veins, and venous sinuses.

The **superficial veins** lie in the superficial fascia, beneath the skin; they return the blood from these structures, and communicate with the deep veins.

The **deep veins** accompany the arteries, and are usually enclosed in the same sheaths with those vessels. With the smaller arteries—as the radial, ulnar, brachial, tibial, peroneal—they exist generally in pairs, one lying on either side of the artery, and are called *venæ comitantes*. The larger arteries—such as the axillary, subclavian, popliteal, and femoral—have usually only one accompanying vein. In certain regions, however, the deep veins do not accompany the arteries; for instance, the veins in the skull and vertebral canal, the hepatic veins in the liver, and the larger veins returning blood from the bones.

Venous sinuses are found only in the interior of the skull, and are canals between the two layers of the dura mater.

PULMONARY VEINS

The **pulmonary veins** return the arterialised blood from the lungs to the left atrium of the heart. They are four in number, two from each lung, and are destitute of valves. They commence in a capillary network upon the walls of the alveoli of the lungs, where they are continuous with the capillary ramifications of the pulmonary arteries, and, joining together, form one vessel from each lobule of the lung. These vessels, uniting successively, form a single trunk from each lobe, three from the right lung and two from the left. The vein from the middle lobe of the right lung generally unites with that from the upper lobe, so that ultimately two trunks from each lung are formed; they perforate the fibrous layer of the pericardium and open separately into the upper and posterior part of the left atrium. Occasionally the three veins on the right side remain separate. Sometimes the two left pulmonary veins end by a common opening.

At the root of the lung, the superior pulmonary vein lies in front of and a little below the pulmonary artery; the inferior is situated at the lowest part of the hilum of the lung and on a plane posterior to the upper vein. Behind the pulmonary artery is the bronchus.

The right pulmonary veins pass behind the right atrium and superior vena cava; the left in front of the descending thoracic aorta.

Within the pericardium, their anterior surfaces are invested by the serous layer of this membrane.

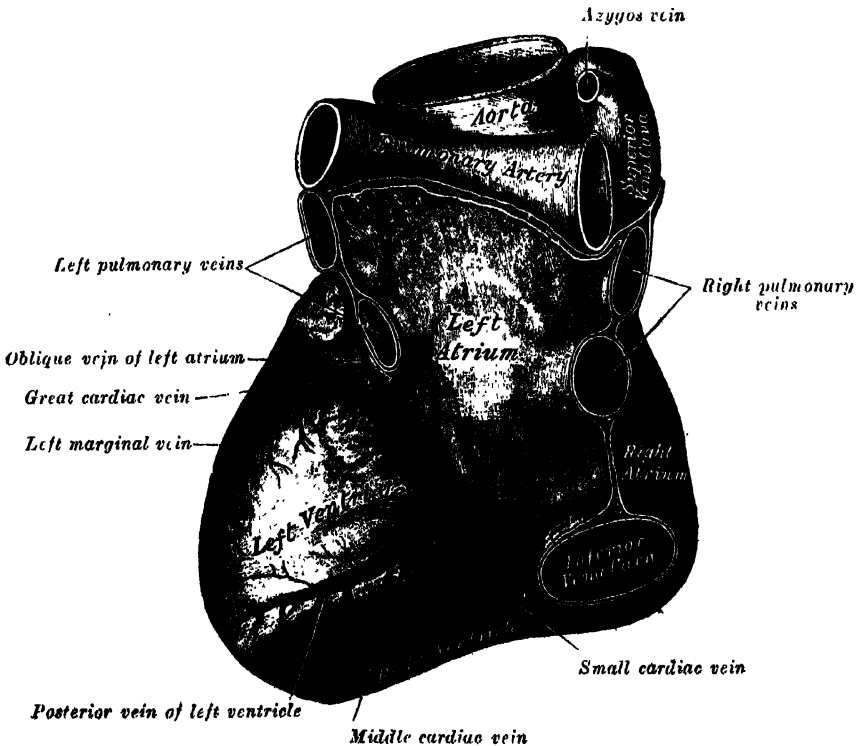
THE SYSTEMIC VEINS

The **systemic veins** may be arranged into three groups: 1. The veins of the heart. 2. The veins of the upper extremities, head, neck, and thorax, which end in the superior vena cava. 3. The veins of the lower extremities, abdomen, and pelvis, which end in the inferior vena cava.

VEINS OF THE HEART (fig. 662)

Coronary sinus.—Most of the veins of the heart open into the coronary sinus. This is a wide venous channel about 2.25 cm. long, situated in the

FIG. 662.—Base and diaphragmatic surface of heart.



posterior part of the coronary sulcus of the heart, between the left atrium and left ventricle, and covered by muscular fibres from the left atrium. It ends in the right atrium between the opening of the inferior vena cava and the atrio-ventricular orifice, its aperture being guarded by a semilunar valve, the *valve of the coronary sinus* (valve of Thebesius).

Its tributaries are the great, small, and middle cardiac veins, the posterior vein of the left ventricle, and the oblique vein of the left atrium, all of which, except the last, are provided with valves at their orifices.

1. The **great cardiac vein** begins at the apex of the heart and ascends in the anterior longitudinal sulcus to the bases of the ventricles. It then curves to the left in the coronary sulcus, and, reaching the back of the heart, opens into the left extremity of the coronary sinus. It receives tributaries from the left atrium and from both ventricles: one, the *left marginal vein*, is of considerable size, and ascends along the left margin of the heart.

2. The **small cardiac vein** runs in the coronary sulcus between the right atrium and ventricle, and opens into the right extremity of the coronary sinus. It receives blood from the back of the right atrium and ventricle; the *right marginal vein* ascends along the right margin of the heart and joins the small cardiac vein in the coronary sulcus, or opens directly into the right atrium.

3. The **middle cardiac vein** begins at the apex of the heart, ascends in the posterior longitudinal sulcus, and ends in the coronary sinus near its right extremity.

4. The **posterior vein of the left ventricle** runs on the diaphragmatic surface of the left ventricle to the coronary sinus, but may end in the great cardiac vein.

5. The **oblique vein of the left atrium** (oblique vein of Marshall) is a small vessel which descends obliquely on the back of the left atrium and ends in the coronary sinus near its left extremity; it is continuous above with the *ligament of the left vena cava* (vestigial fold of Marshall), and the two structures are remnants of the left duct of Cuvier.

The following cardiac veins do not end in the coronary sinus: (1) the **anterior cardiac veins**, comprising three or four small vessels which collect blood from the front of the right ventricle and open into the right atrium; the right marginal vein frequently opens into the right atrium, and is therefore sometimes regarded as belonging to this group; (2) the **smallest cardiac veins** (vv. cordis minimæ), consisting of a number of minute veins which arise in the muscular wall of the heart; most of them open into the atria, but a few end in the ventricles.

VEINS OF THE HEAD AND NECK

The veins of the head and neck may be subdivided into three groups:

1. The veins of the exterior of the head and face.
2. The veins of the neck.
3. The diploic veins, the veins of the brain, and the venous sinuses of the dura mater.

VEINS OF THE EXTERIOR OF THE HEAD AND FACE (fig. 663)

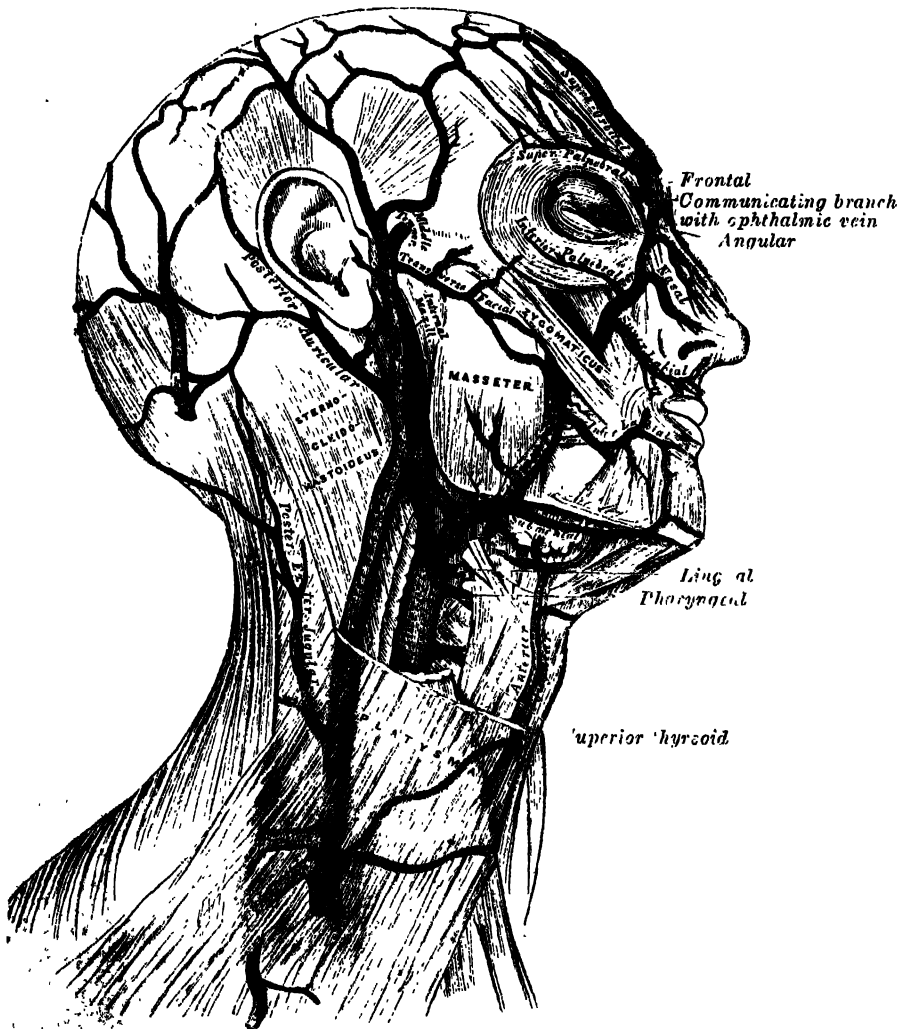
Frontal.	Superficial temporal.
Supraorbital.	Internal maxillary.
Angular.	Posterior facial.
Anterior facial.	Posterior auricular.
	Occipital.

The **frontal vein** begins on the forehead in a venous network which communicates with the frontal tributaries of the superficial temporal vein. Veins converge from the network to form a single trunk, which descends near the middle line of the forehead parallel with the vein of the opposite side. At the root of the nose the two veins are joined by a transverse branch which is called the *nasal arch* and receives some small veins from the dorsum of the nose. The frontal veins then diverge, and at the medial angle of the orbit, each joins with the *supraorbital vein* to form the *angular vein*. Occasionally the frontal veins unite in a single trunk, which bifurcates at the root of the nose into two angular veins.

The **supraorbital vein** begins on the forehead, where it communicates with the frontal tributary of the superficial temporal vein. It descends superficially to the Frontalis muscle, and at the medial angle of the orbit joins the frontal vein to form the *angular vein*; it receives the frontal diploic vein, and communicates with the superior ophthalmic vein.

The **angular vein**, formed by the junction of the frontal and supraorbital veins, runs obliquely downwards on the side of the root of the nose, to the level of the lower margin of the orbit, where it becomes the anterior facial vein. It receives the veins of the ala nasi, and communicates with the superior ophthalmic vein through the nasofrontal vein, thus establishing an anastomosis between the anterior facial vein and the cavernous sinus.

FIG. 663.—Veins of the head and neck.



The **anterior facial vein** (facial vein) begins at the side of the nose as a direct continuation of the angular vein. It lies behind the external maxillary (facial) artery and follows a less tortuous course. It runs obliquely downwards and backwards, beneath the *Zygomaticus* and zygoma, head of the *Quadratus labii superioris*, descends along the anterior border and then on the superficial surface of the *Masseter*, crosses over the body of the mandible, and passes obliquely backwards, beneath the *Platysma* and cervical fascia, superficial to the submaxillary gland, *Digastricus*, and *Stylohyoideus*. It unites with the anterior branch of the posterior facial vein to form the **common facial vein**, which crosses the external carotid artery and enters the internal jugular vein at a variable point below the hyoid bone. From near its termination a branch, often runs down the anterior border of the *Sternocleidomastoideus* to join the lower part of the anterior jugular vein.

ANGIOLOGY

Tributaries.—The anterior facial vein receives a branch of considerable size, the *deep facial vein*, from the pterygoid venous plexus. It is also joined by the superior and inferior palpebral, the superior and inferior labial, the buccinator and the masseteric veins. Below the mandible it receives the submental, palatine, and submaxillary veins, and, generally also, the vena comitans of the hypoglossal nerve.

Applied Anatomy.—There are some points about the anterior facial vein which render it of great importance in surgery. It is not so flaccid as are most superficial veins, and, in consequence of this, remains more patent when divided. It has, moreover, no valves. It communicates freely with the intracranial circulation, not only at its commencement by the angular and supraorbital veins which are connected with the ophthalmic vein, a tributary of the cavernous sinus, but also by the deep facial vein, which communicates through the pterygoid plexus with the cavernous sinus by branches passing through the foramen ovale and foramen lacerum (p. 687). These facts have an important bearing upon the surgery of some diseases; any phlegmonous inflammation of the face following a poisoned wound is liable to set up thrombosis in the anterior facial vein, and detached portions of the clot may give rise to purulent foci in other parts of the body. These thrombi may extend upwards into the cranial sinuses, and so induce a fatal issue; this has been known to follow in cases of ordinary carbuncle of the face. The position of the vein must be borne in mind when incisions are made for the relief of suppuration about the mandible.

The **superficial temporal vein** begins on the side and vertex of the skull in a network which joins with the corresponding vein of the opposite side, and with the frontal, supraorbital, posterior auricular and occipital veins. From this network, frontal and parietal branches arise, and unite above the zygomatic arch to form the superficial temporal vein, which is joined in this situation by the *middle temporal vein*, from the substance of the Temporalis muscle. It then crosses the posterior root of the zygomatic arch, enters the substance of the parotid gland, and unites with the internal maxillary vein to form the posterior facial vein.

Tributaries.—The superficial temporal vein receives some veins from the parotid gland, articular veins from the temporomandibular joint, anterior auricular veins from the auricula, and the *transverse facial* from the side of the face. The middle temporal vein receives the *orbital vein*, which is formed by some lateral palpebral branches, and passes backwards between the layers of the temporal fascia to join the superficial temporal vein.

The **pterygoid plexus** is of considerable size, and is situated partly between the Temporalis and Pterygoideus externus, and partly between the two Pterygoidei. Its tributaries correspond with the branches of the internal maxillary artery; thus, it receives the sphenopalatine, middle meningeal, deep temporal, pterygoid, masseteric, buccinator, alveolar, and some palatine veins, and a branch which communicates with the inferior ophthalmic vein through the inferior orbital fissure. The pterygoid plexus anastomoses with the anterior facial vein, through the deep facial vein; it is also connected with the cavernous sinus by veins which pass through the foramen Vesalii, foramen ovale, and foramen lacerum.

The **internal maxillary vein** is a short trunk which accompanies the first part of the internal maxillary artery and is formed by a confluence of the veins of the pterygoid plexus. It passes backwards between the sphenomandibular ligament and the neck of the mandible, and unites with the temporal vein to form the posterior facial vein.

The **posterior facial vein** (temporomaxillary vein), formed by the union of the superficial temporal and internal maxillary veins, descends in the substance of the parotid gland, superficial to the external carotid artery but deep to the facial nerve, between the ramus of the mandible and the Sternocleidomastoideus muscle. It divides into two branches, an anterior, which passes forwards and unites with the anterior facial vein to form the common facial vein, and a posterior, which is joined by the posterior auricular vein and becomes the external jugular vein.

The **posterior auricular vein** begins upon the side of the head, in a network which communicates with the tributaries of the occipital and superficial temporal veins. It descends behind the auricula, and joins the posterior division of the posterior facial vein to form the external jugular vein. It receives the stylomastoid vein and some tributaries from the cranial surface of the auricula.

The **occipital vein** begins in a venous network at the posterior part of the skull. It pierces the cranial attachment of the Trapezius, dips into the suboccipital triangle

and joins the deep cervical and vertebral veins. Occasionally it follows the course of the occipital artery and ends in the internal jugular vein; sometimes it joins the posterior auricular vein and through it opens into the external jugular vein. The parietal emissary vein connects it with the superior sagittal sinus, and the mastoid emissary vein with the transverse sinus. The occipital diploic vein sometimes joins it.

VEINS OF THE NECK (fig. 663)

External jugular. Anterior jugular.
Posterior external jugular. Internal jugular.
Vertebral.

The **external jugular vein** receives the greater part of the blood from the exterior of the cranium and from the deep parts of the face, and is formed by the union of the posterior division of the posterior facial vein with the posterior auricular vein. It begins in the substance of the parotid gland, on a level with the angle of the mandible, and runs down the neck, where its course is represented by a line drawn from the angle of the mandible to the middle of the clavicle at the posterior border of the *Sternocleidomastoideus*. It crosses the *Sternocleidomastoideus* obliquely, and in the subclavian triangle perforates the deep fascia, and ends in the subclavian vein, lateral to or in front of the *Scalenus anterior*. It is separated from the *Sternocleidomastoideus* by the investing layer of the deep cervical fascia, and is covered by the *Platysma*, superficial fascia, and skin; it crosses the cutaneous cervical nerve, and its upper half runs parallel with the great auricular nerve. The external jugular vein varies in size, bearing an inverse proportion to the other veins of the neck; it is occasionally double. It is provided with two pairs of valves, a lower pair at its entrance into the subclavian vein, an upper about 4 cm. above the clavicle. The portion of the vein between the two sets of valves is often dilated, and is termed the *sinus*. These valves do not prevent regurgitation of the blood, or the passage of injection from below upwards.

Tributaries.—This vein receives the posterior external jugular, and, near its termination, the transverse cervical, transverse scapular, and anterior jugular veins; in the substance of the parotid gland, a large branch from the internal jugular joins it. The occipital vein occasionally opens into it.

The **posterior external jugular vein** begins in the occipital region and returns the blood from the skin and superficial muscles in the upper and posterior part of the neck. It opens into the middle part of the external jugular vein.

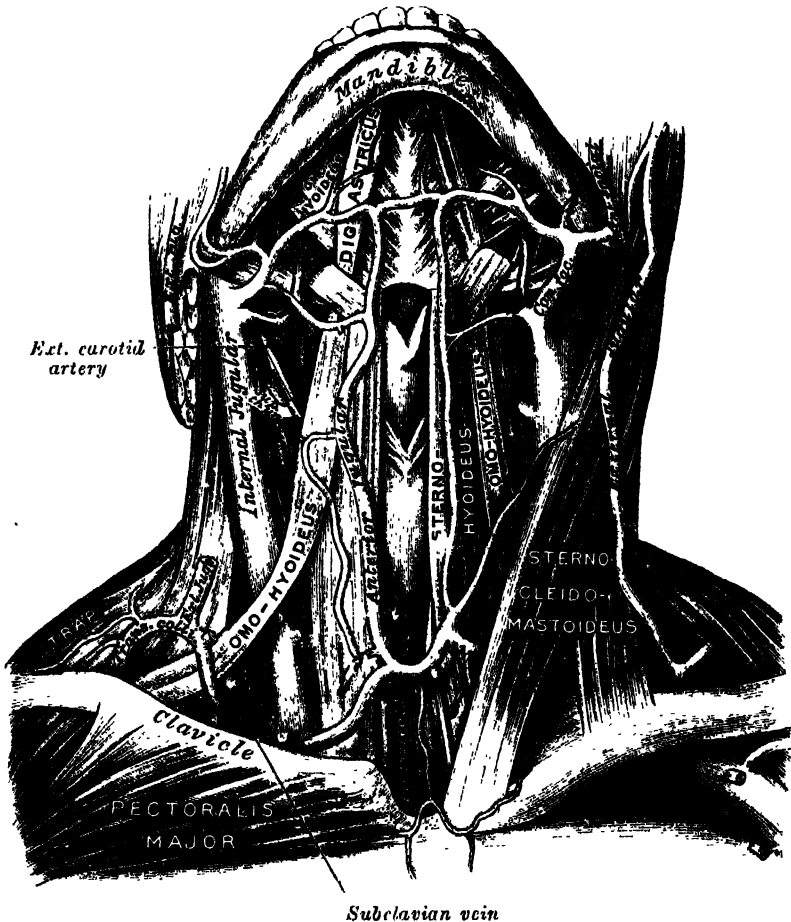
The **anterior jugular vein** is devoid of valves and begins near the hyoid bone by the confluence of several superficial veins from the submaxillary region. It descends between the median line and the anterior border of the *Sternocleidomastoideus*, and, at the lower part of the neck, turns lateralwards beneath that muscle to open into the termination of the external jugular vein, or into the subclavian vein (figs. 663, 664). It varies considerably in size, bearing usually an inverse proportion to the external jugular; most frequently there are two anterior jugulars, a right and left; but sometimes only one. It communicates with the internal jugular vein and receives as tributaries some laryngeal veins, and occasionally a small thyroid vein. Just above the sternum, the two anterior jugular veins are united to one another by a transverse trunk, the *venous jugular arch*, which receives tributaries from the inferior thyroid veins.

Applied Anatomy.—Venesection used formerly to be performed on the external jugular vein, but is now probably never resorted to. The point to be remembered in performing this operation is to cut across the fibres of the *Platysma* in opening the vein, so that by their contraction they will expose the orifice in the vein and so allow the flow of blood.

The **internal jugular vein** collects the blood from the brain, from the superficial parts of the face, and from the neck. It is directly continuous with the transverse sinus of the cranium, and begins at the base of the skull in the posterior compartment of the jugular foramen. At its origin it is somewhat dilated, and this dilatation is called the *superior bulb*. It runs down the side of the neck, lying at first laterally to the internal carotid artery, and then laterally

to the common carotid artery. At the root of the neck it unites with the subclavian vein to form the innominate vein; a little above its termination is a second dilatation, the *inferior bulb*. In the upper part of its course, it lies upon the Rectus capitis lateralis, behind the internal carotid artery and the nerves passing through the jugular foramen; lower down, the vein and artery lie upon the same plane, the glossopharyngeal and hypoglossal nerves passing forwards between them; the vagus nerve descends in the same sheath as the vein and artery, but lies between and on a plane posterior to them; the accessory nerve runs obliquely backwards, superficial or deep to the vein. At the root

FIG. 664.—The veins of the neck, viewed from in front. (After Spalteholz.)



of the neck the right internal jugular vein is placed at a little distance from the common carotid artery, and crosses the first part of the subclavian artery, while the left internal jugular vein usually overlaps the common carotid artery. The left vein is generally smaller than the right, and each contains a pair of valves, which are placed about 2.5 cm. above the termination of the vessel.

Tributaries.—The internal jugular vein receives the inferior petrosal sinus, the common facial, lingual, pharyngeal, superior and middle thyroid veins, and sometimes the occipital vein. The thoracic duct opens into the angle of union of the left subclavian and internal jugular veins, and the right lymphatic duct into the angle of union of the right subclavian and internal jugular veins.

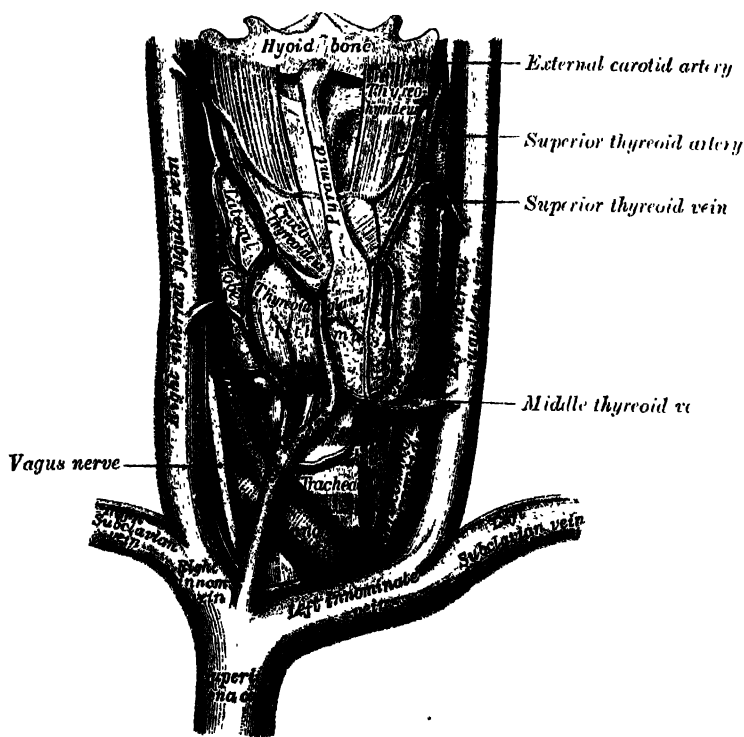
The **inferior petrosal sinus** leaves the skull through the anterior part of the jugular foramen, and joins the superior bulb of the internal jugular vein.

The **lingual veins** begin on the dorsum, sides, and under surface of the tongue, and, passing backwards along the course of the lingual artery, end in the internal jugular vein. The **vena comitans hypoglossi** (ranine vein), a branch of considerable size, begins below the tip of the tongue, and may join the lingual veins; generally, however, it passes backwards superficially to the Hyoglossus, and opens into the common facial vein.

The **pharyngeal veins** begin in the *pharyngeal plexus* on the outer surface of the pharynx, and, after receiving some posterior meningeal veins and the vein of the pterygoid canal, end in the internal jugular vein. They occasionally open into the facial, the lingual, or the superior thyroid vein.

The **superior thyroid vein** (fig. 665) begins in the substance and on the surface of the thyroid gland, by tributaries corresponding with the branches of the superior thyroid artery, and ends in the upper part of the internal jugular vein. It receives the superior laryngeal and cricothyroid veins.

FIG. 665.—The veins of the thyroid gland.



The **middle thyroid vein** (fig. 665) collects the blood from the lower part of the thyroid gland, receives some veins from the larynx and trachea, and ends in the lower part of the internal jugular vein.

The **common facial and occipital veins** have been described.

Applied Anatomy.—The internal jugular vein requires ligature in cases of septic thrombosis of the transverse sinus, in order to prevent septic emboli being carried into the general circulation. This operation has been performed in many cases, with the most satisfactory results. The cases are generally those of chronic disease of the middle ear, with discharge of pus which perhaps has existed for many years. The patient is seized with acute septic inflammation, spreading to the mastoid cells, and setting up septic thrombosis of the transverse sinus and extending downwards into the internal jugular vein. Such cases are always extremely grave, for there is a danger of porticus of the thrombus or clot being detached and causing septic embolism in the lungs. If the condition be suspected, the diseased bone should be removed at once from the mastoid process. The sinus is then investigated, and if it be found thrombosed, the surgeon should proceed to ligature the internal jugular vein, through an incision along the anterior

border of the Sternocleidomastoideus, the centre of the incision being on a level with the greater cornu of the hyoid bone. The vein should be ligatured in two places and divided between. After the vessel has been secured and divided, the transverse sinus is to be thoroughly cleared out, and, by removing the ligature from the upper end of the divided vein, all septic clots removed by syringing from the sinus through the vein. If hæmorrhage occur from the distal end of the sinus, it can be arrested by careful plugging with antiseptic gauze.

The internal jugular vein is also surgically important, because it is surrounded by a number of deep cervical lymph-glands; and when these are enlarged in tuberculous or malignant disease, they are apt to adhere to the vessel, rendering their removal difficult and often dangerous. The proper course to pursue in these cases is to ligature the vessel above and below the glandular mass, and remove the included portion with the glands.

Cardiac pulsation is often demonstrable in the internal jugular vein at the root of the neck. There are no valves in the innominate veins or superior vena cava; in consequence, the systole of the right atrium causes a wave to pass up these vessels, and when the conditions are favourable this wave appears as a somewhat feeble flicker over the internal jugular vein at the root of the neck, quite distinct from, and just preceding, the more forcible impulse transmitted from the underlying common carotid artery and due to the ventricular systole. This atrial systolic venous impulse is much increased in conditions in which the right atrium is abnormally distended with blood or is hypertrophied, as is often the case in disease of the bicuspid valve. In the Adam-Stokes' syndrome (p. 565) it is this pulsation which gives evidence of the fact that the atria are beating faster—often two or three times faster—than the ventricles.

The **vertebral vein** is formed in the suboccipital triangle, from numerous small tributaries which spring from the internal vertebral venous plexuses and issue from the vertebral canal above the posterior arch of the atlas. They unite with small veins from the deep muscles at the upper part of the back of the neck, and form a vessel which enters the foramen in the transverse process of the atlas, and descends, forming a dense plexus around the vertebral artery, in the canal formed by the foramina transversaria of the cervical vertebræ. This plexus ends in the vertebral vein, which emerges from the foramen transversarium of the sixth cervical vertebra, and opens into the upper and posterior part of the innominate vein, the opening being guarded by a pair of valves. On the right side, it crosses the first part of the subclavian artery.

Tributaries.—The vertebral vein communicates with the transverse sinus of the skull by a vein which passes through the condyloid canal, when that canal exists. It receives branches from the occipital vein, from the prevertebral muscles, and from the internal and external vertebral venous plexuses. It is joined by the anterior vertebral and the deep cervical veins; close to its termination it sometimes receives the first intercostal vein.

The **anterior vertebral vein** commences in a plexus around the transverse processes of the upper cervical vertebræ, descends in company with the ascending cervical artery between the Scalenus anterior and Longus capitis muscles, and opens into the terminal part of the vertebral vein.

The **deep cervical vein** accompanies its artery between the Semispinales capitis and colli. It begins in the suboccipital region by communicating branches from the occipital vein and by small veins from the deep muscles at the back of the neck. It receives tributaries from the plexuses around the spinous processes of the cervical vertebræ, and passes forwards between the transverse process of the seventh cervical vertebra and the neck of the first rib to end in the lower part of the vertebral vein.

DIPLOIC VEINS (fig. 666)

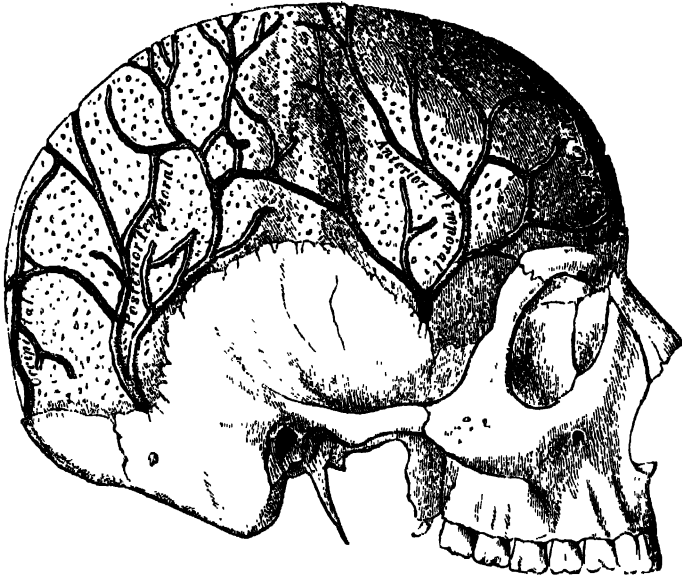
The diploic veins occupy channels in the diploë of the cranial bones.

They are large, and exhibit at irregular intervals pouch-like dilatations; their walls are thin, and formed of endothelium supported by a layer of elastic tissue.

They communicate with the meningeal veins, the sinuses of the dura mater, and the veins of the pericranium. They consist of (1) the *frontal diploic vein*, which opens into the supraorbital vein and the superior sagittal sinus; (2) the *anterior temporal diploic vein*, which is confined chiefly to the frontal bone, and pierces the great wing of the sphenoidal bone to end in the sphenoparietal sinus or in the anterior deep temporal vein; (3) the *posterior temporal diploic vein*, which is situated in the parietal bone; it descends to the mastoid angle

of the parietal bone, and joins the transverse sinus through an aperture at the mastoid angle of the parietal bone or through the mastoid foramen; and

FIG. 666.—Veins of the diploë as displayed by the removal of the outer table of the skull.



(4) the *occipital diploic vein*, the largest of the four, which is confined to the occipital bone, and opens into the occipital vein or into the transverse sinus.

VEINS OF THE BRAIN

The veins of the brain possess no valves, and their walls, owing to the absence of muscular tissue, are extremely thin. They pierce the arachnoid membrane and the inner or meningeal layer of the dura mater, and open into the cranial venous sinuses. They consist of two sets, cerebral and cerebellar.

The **cerebral veins** are divisible into external and internal groups according as they drain the outer surfaces or the inner parts of the hemispheres.

The **external cerebral veins** are the superior, middle, and inferior.

The *superior cerebral veins*, eight to twelve in number, drain the superior, lateral, and medial surfaces of the hemispheres, and are mainly lodged in the sulci between the gyri, but some run across the gyri. They open into the superior sagittal sinus; the anterior veins run nearly at right angles to the sinus; the posterior and larger veins are directed obliquely forwards, and thus open into the sinus in a direction more or less opposed to the current of the blood contained within it.

The *middle cerebral vein* (superficial Sylvian vein) begins on the lateral surface of the hemisphere, and, running along the lateral cerebral fissure, ends in the cavernous sinus or the sphenoparietal sinus. It is connected (a) with the superior sagittal sinus by the *great anastomotic vein of Trolard*, which opens into one of the superior cerebral veins; (b) with the transverse sinus by the *posterior anastomotic vein of Labbé*, which courses over the temporal lobe.

The *inferior cerebral veins*, of small size, drain the under surfaces of the hemispheres. Those on the orbital surface of the frontal lobe join the superior cerebral veins, and through these open into the superior sagittal sinus; those of the temporal lobe anastomose with the basal and middle cerebral veins, and join the cavernous sphenoparietal, and superior petrosal sinuses.

The **basal vein** is formed at the anterior perforated substance by the union of (a) a small *anterior cerebral vein* which accompanies the anterior cerebral artery, (b) the *deep middle cerebral vein* (deep Sylvian vein), which receives tributaries

from the insula and neighbouring gyri, and runs in the lower part of the lateral cerebral fissure, and (c) the *inferior striate veins* which leave the corpus striatum through the anterior perforated substance. The basal vein passes backwards round the cerebral peduncle, and ends in the internal cerebral vein (vein of Galen); it receives tributaries from the interpeduncular fossa, the inferior horn of the lateral ventricle, the hippocampal gyrus, and the mid-brain.

The *internal cerebral veins* (veins of Galen), two in number, drain the deep parts of the hemisphere; each is formed near the interventricular foramen by the union of the *terminal* and *chorioid veins*. They run backwards parallel with one another, between the layers of the tela chorioidea of the third ventricle, and beneath the splenium of the corpus callosum, where they unite to form a short trunk, the *great cerebral vein*; just before their union each receives the corresponding basal vein.

The *terminal vein* (*vena corporis striati*) runs in the groove between the corpus striatum and thalamus, receives numerous veins from both of these structures, and unites behind the crus fornicis with the chorioid vein, to form one of the internal cerebral veins. The *chorioid vein* runs along the whole length of the chorioid plexus, and receives veins from the hippocampus, the fornix, and the corpus callosum.

The *great cerebral vein* (*vena magna Galeni*), formed by the union of the two internal cerebral veins, is a short median trunk which curves backwards and upwards around the splenium of the corpus callosum and ends in the anterior extremity of the straight sinus.

The *cerebellar veins* are placed on the surface of the cerebellum, and consist of two sets, superior and inferior. The *superior cerebellar veins* pass partly forwards and medialwards, across the superior vermis, to end in the straight sinus and the internal cerebral veins, partly lateralwards to the transverse and superior petrosal sinuses. The *inferior cerebellar veins*, of large size, end in the transverse, superior petrosal, and occipital sinuses.

VENOUS SINUSES OF THE DURA MATER

The sinuses of the dura mater are venous channels which drain the blood from the brain; they are situated between the two layers of the dura mater and are lined by endothelium continuous with that which lines the veins; they contain no valves and their walls are devoid of muscular tissue. They may be divided into two groups: (1) a posterosuperior, at the upper and posterior part of the skull, and (2) an antero-inferior, at the base of the skull.

Posterosuperior group:

Superior sagittal.

Inferior sagittal.

Straight.

Two transverse.

Occipital.

The *superior sagittal sinus* (superior longitudinal sinus) (figs. 667, 668) occupies the attached or convex margin of the falx cerebri. (Commencing at the foramen cæcum, through which it receives a vein from the nasal cavity, it runs backwards, grooving the inner surface of the frontal bone, the adjacent margins of the two parietal bones, and the superior division of the cruciate eminence of the occipital bone; near the internal occipital protuberance it deviates to one or other side (usually the right), and is continued as the corresponding transverse sinus.) It is triangular in section, and gradually increases in size as it passes backwards. On its inner surface are the openings of the superior cerebral veins, and numerous fibrous bands (*chordæ Willisii*) which cross the inferior angle of the sinus; the sinus also communicates through small openings with irregularly-shaped *venous lacunæ* in the dura mater near the sinus. There are usually three venous lacunæ on either side of the sinus: a small frontal, a large parietal, and an occipital which is intermediate in size between the other two (Sargent *). Many of the cerebral veins from the lateral surface of the hemisphere open into these lacunæ, and numerous arachnoidal granulations (Pacchionian bodies) project into them from below. (The superior

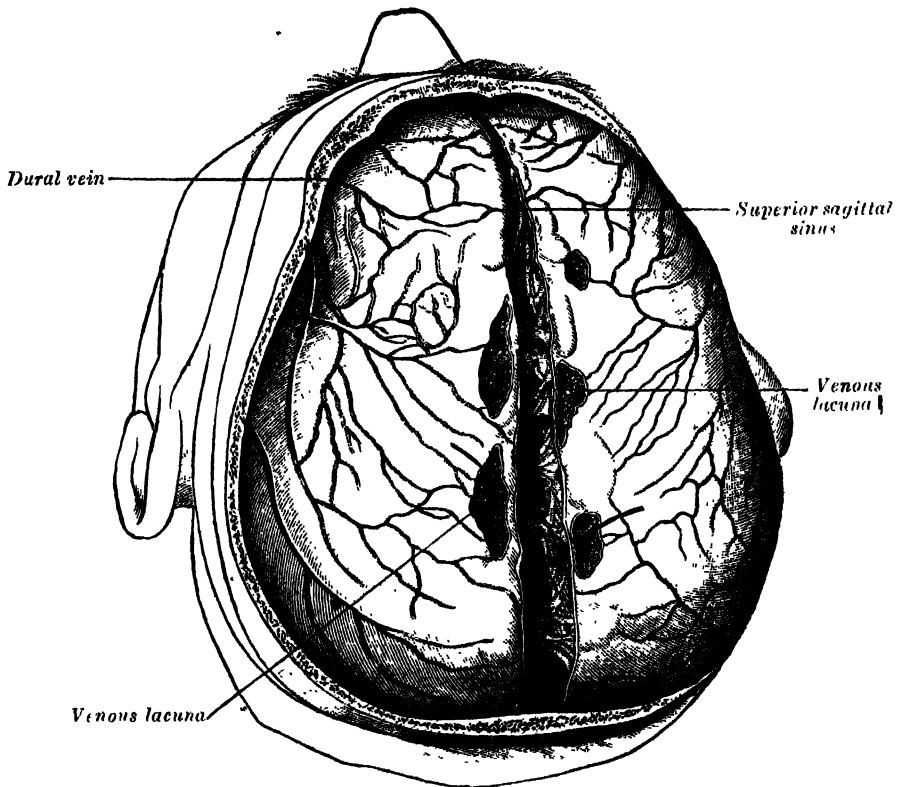
* *Journal of Anatomy and Physiology*, vol. xlv.

sagittal sinus receives the superior cerebral veins, veins from the diploë and dura mater, and, near the posterior extremity of the sagittal suture, veins from the pericranium, which pass through the parietal foramina.)

Applied Anatomy.—The numerous communications which take place between this sinus and the veins of the nose, scalp, and diploë, cause it to be at times the seat of infective thrombosis from suppurative processes in these parts.

The inferior sagittal sinus (inferior longitudinal sinus) (fig. 668) is contained in the posterior half or two-thirds of the free margin of the falx cerebri. It increases in size as it passes backwards, and ends in the straight sinus. It

FIG. 667.—Superior sagittal sinus laid open after removal of the skull-cap. The chordæ Willisii and venous lacunæ are clearly seen; from two of the lacunæ probes are passed into the sinus. (Poirier and Charpy.)



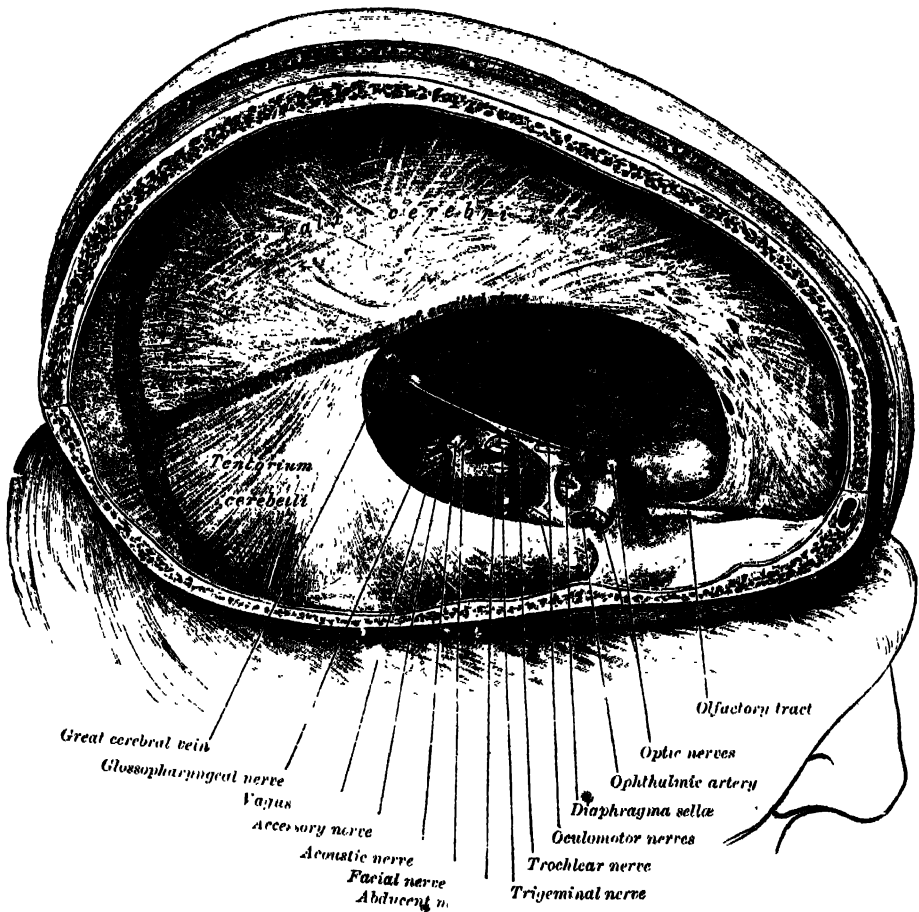
receives several veins from the falx cerebri, and occasionally a few from the medial surfaces of the hemispheres.

The straight sinus (figs. 668, 669) is situated at the line of junction of the falx cerebri with the tentorium cerebelli. It is triangular in section, and runs backwards and downwards from the end of the inferior sagittal sinus to the transverse sinus of the side opposite to that into which the superior sagittal sinus is prolonged. Its terminal part communicates by a cross branch with the confluence of the sinuses. Besides the inferior sagittal sinus, it receives the great cerebral vein (vena magna Galeni) and some of the superior cerebellar veins. A few transverse bands cross its interior.

The transverse sinuses (lateral sinuses) (figs. 669, 670) are of large size, and begin at the internal occipital protuberance; one, generally the right, being the direct continuation of the superior sagittal sinus, the other of the straight sinus. Each transverse sinus passes lateralwards and forwards, describing a slight curve with its convexity upwards, to the base of the petrous portion of the temporal bone and lies, in this part of its course, in the attached

margin of the tentorium cerebelli; it then leaves the tentorium and curves downwards and medialwards to reach the posterior part of the jugular foramen, through which it passes, and ends in the internal jugular vein. It rests successively upon the squama of the occipital bone, the mastoid angle of the parietal bone, the mastoid part of the temporal bone, and the jugular process of the occipital bone; the portion which occupies the groove on the mastoid part of the temporal bone is sometimes termed the *sigmoid sinus*. The transverse sinuses are frequently of unequal size, that formed by the superior sagittal

FIG. 668.—Dura mater and its processes, exposed by removing part of the right half of the skull, and the brain.

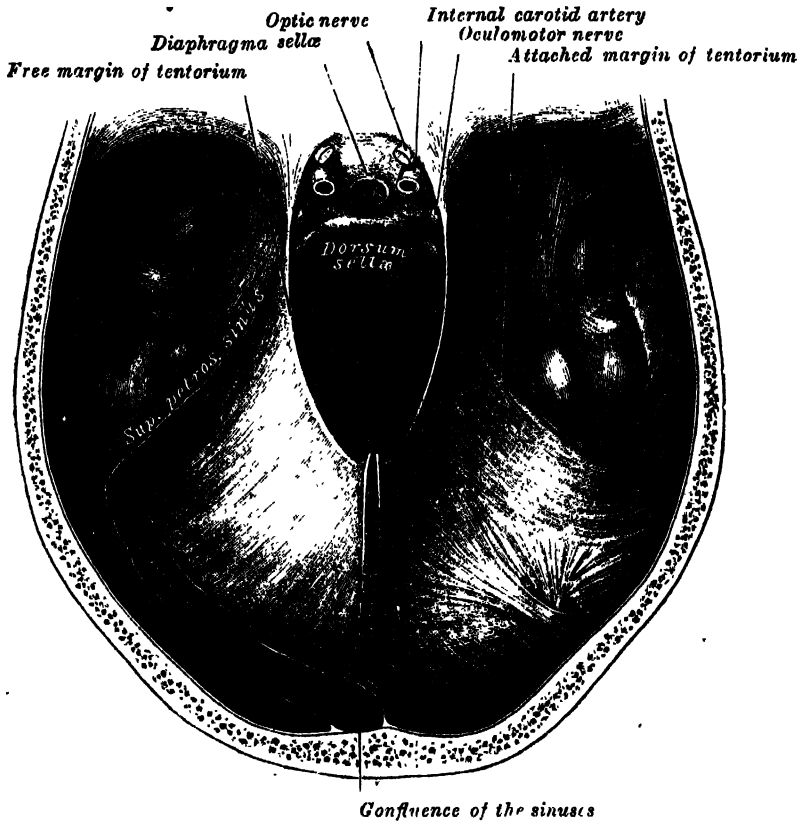


sinus being the larger; they increase in size as they proceed from behind forwards. On transverse section the horizontal portion of the sinus exhibits a prismatic, the curved portion a semicylindrical, form. They communicate with the veins of the pericranium by means of the mastoid and condyloid emissary veins, and receive the superior petrosal sinuses, some inferior cerebral, inferior cerebellar and diploic veins. The *petrosquamous sinus*, when present, runs backwards along the junction of the squama and petrous portion of the temporal bone, and opens into the transverse sinus.

The *occipital sinus* (fig. 670), the smallest of the cranial sinuses, is situated in the attached margin of the falx cerebelli, and is generally single, but occasionally there are two. It commences around the margin of the foramen magnum by several small venous channels, one of which joins the terminal part of the transverse sinus; it communicates with the posterior internal vertebral venous plexuses, and ends in the confluence of the sinuses.

The *confluence of the sinuses*, or *torcular Herophili*, is the term applied to the dilated extremity of the superior sagittal sinus. It is lodged on one side (generally the right) of the internal occipital protuberance, and from it the transverse sinus of the same side is derived. It receives also the blood from the occipital sinus, and is connected by a channel with the commencement of the opposite transverse sinus.

FIG. 669.—Tentorium cerebelli from above.



2. Antero-inferior group:

Two cavernous.

Two intercavernous.

Two superior petrosal.

Two inferior petrosal.

Basilar plexus.

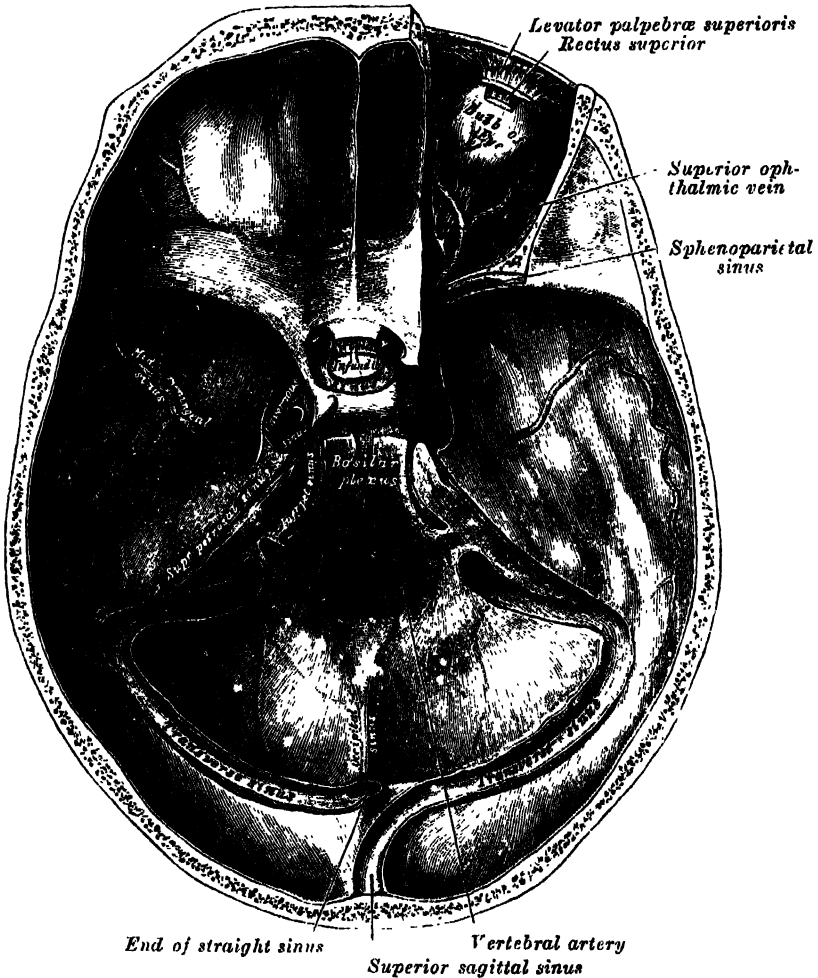
The **cavernous sinuses** (figs. 670, 671) are so named because they present a **reticulated structure**, due to their being traversed by numerous interlacing **filaments**. They are of irregular form, larger behind than in front, and are placed one on either side of the body of the sphenoidal bone, extending from the superior orbital fissure to the apex of the petrous portion of the temporal bone; they open behind into the petrosal sinuses. On the medial wall of each sinus is the internal carotid artery, accompanied by filaments of the carotid plexus; near the artery is the abducent nerve; on the lateral wall are the oculomotor and trochlear nerves, and the ophthalmic and maxillary divisions of the trigeminal nerve (fig. 671). These structures are separated from the blood in the sinus by the lining membrane of the sinus.

The cavernous sinus receives the superior ophthalmic vein, and a branch from the inferior ophthalmic vein, through the superior orbital fissure, some of the inferior cerebral veins, and also the *sphenoparietal sinus* which courses along the under surface of the small wing of the sphenoid. It communicates with the transverse sinus by means of the superior petrosal sinus; with the

internal jugular vein through the inferior petrosal sinus and a plexus of veins on the internal carotid artery; with the pterygoid venous plexus by veins which pass through the foramen Vesalii, foramen ovale, and foramen lacerum, and with the angular vein through the superior ophthalmic vein. The two sinuses also communicate with each other by means of the anterior and posterior intercavernous sinuses and the basilar plexus.)

Applied Anatomy.—An arteriovenous communication may be established between the cavernous sinus and the internal carotid artery, giving rise to a pulsating tumour

FIG. 670.—The sinuses at the base of the skull.



in the orbit. Such communication may be the result of a bullet wound, a stab, or a blow or fall sufficiently severe to cause a fracture of the base of the skull in this situation. The symptoms are sudden noise and pain in the head, followed by exophthalmos, swelling and congestion of the eyelids and conjunctivæ, and development of a pulsating tumour at the margin of the orbit, with thrill and the characteristic bruit; accompanying these symptoms there may be impairment of sight, paralysis of the iris and orbital muscles, and pain of varying intensity. In some cases the opposite orbit becomes affected by the passage of the arterial blood into the opposite sinus by means of the intercavernous sinuses; or the arterial blood may find its way through the emissary veins (p. 686) into the pterygoid plexus, and thence into the veins of the face. Pulsating tumours of the orbit may also be due to traumatic aneurysm of one of the orbital arteries, and symptoms resembling those of pulsating tumour may be produced by the pressure of an aneurysm of the internal carotid artery upon the ophthalmic veins as they enter the sinus. Ligature

of the internal or common carotid artery has been performed in these cases with considerable success.

It is now well known that caries in the upper parts of the nasal cavities and suppuration in certain of the accessory sinuses of the nose are frequently responsible for septic thrombosis of the cavernous sinuses, in exactly the same way as thrombosis of the transverse sinus is due to septic disease in the mastoid process. Many deaths from meningitis, hitherto unaccounted for, are in reality due to the spread of an infection from the ethmoidal or sphenoidal air-cells to the cavernous sinuses, and thence to the meninges.

The *ophthalmic veins* (fig. 672), two in number, superior and inferior, are devoid of valves.

The *superior ophthalmic vein* begins at the inner angle of the orbit in the *nasofrontal vein* which communicates anteriorly with the angular vein (p. 673). It runs alongside the ophthalmic artery, receives tributaries corresponding to the branches of that vessel, passes between the two heads of the *Rectus lateralis* and through the medial part of the superior orbital fissure, and ends in the cavernous sinus.

The *inferior ophthalmic vein* begins in a venous network at the fore part of the floor and medial wall of the orbit; it receives some veins from the *Rectus inferior*, *Obliquus inferior*, lacrimal sac and eyelids, runs backwards in the lower part of the orbit and divides into two branches. One of these passes

FIG. 671.—Oblique section through the left cavernous sinus. Viewed from behind.

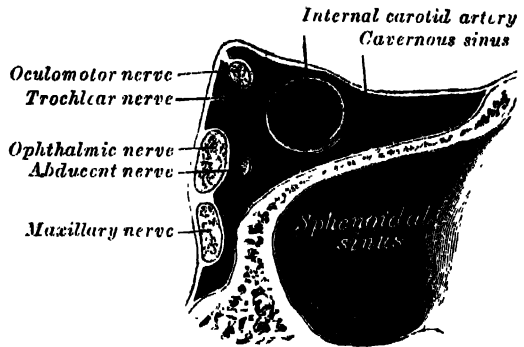
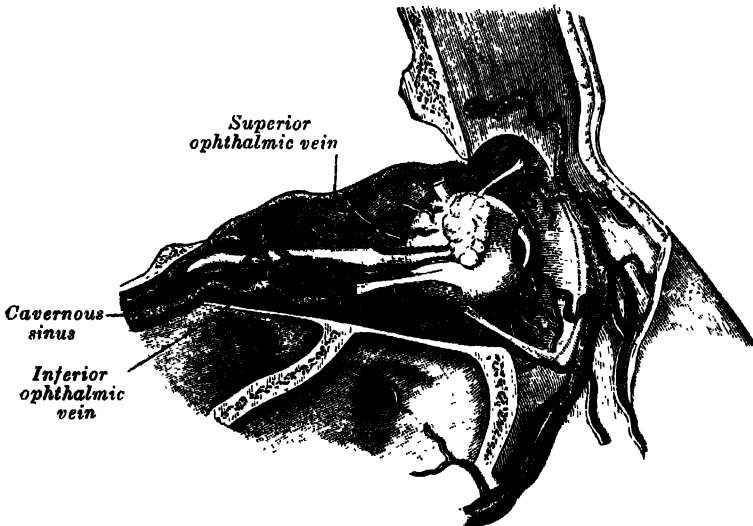


FIG. 672.—Veins of orbit. (Poirier and Charpy.)



through the inferior orbital fissure and joins the pterygoid venous plexus, while the other enters the cranium through the superior orbital fissure and ends in the cavernous sinus, either by a separate opening, or more frequently in common with the superior ophthalmic vein.

The *intercavernous sinuses* (fig. 670) are two in number, an anterior and a posterior, and connect the cavernous sinuses across the middle line. The *anterior*, usually the larger, passes in front of the diaphragma sellæ, the *posterior*

behind it, and they form with the cavernous sinuses a venous circle (*circular sinus*); one or other intercavernous sinus is occasionally absent.

The **superior petrosal sinus** (fig. 670), small and narrow, connects the cavernous with the transverse sinus. It runs lateralwards and backwards, from the posterior end of the cavernous sinus, over the trigeminal nerve, and lies in the attached margin of the tentorium cerebelli and in the superior petrosal sulcus of the temporal bone; it joins the transverse sinus where the latter curves downwards on the inner surface of the mastoid part of the temporal bone. It receives some cerebellar and inferior cerebral veins, and veins from the tympanic cavity.

The **inferior petrosal sinus** (fig. 670) begins in the postero-inferior part of the cavernous sinus, runs backwards in a groove between the petrous part of the temporal bone and the basilar part of the occipital bone, and, passing through the anterior part of the jugular foramen, ends in the superior bulb of the internal jugular vein. It receives the internal auditory veins and also veins from the medulla oblongata, pons, and under surface of the cerebellum.

The relations of the structures transmitted through the jugular foramen are as follows: the inferior petrosal sinus lies medially and anteriorly with the meningeal branch of the ascending pharyngeal artery, and is directed obliquely downwards and backwards; the transverse sinus is situated at the lateral and posterior part of the foramen with a meningeal branch of the occipital artery; between the two sinuses are the glossopharyngeal, vagus, and accessory nerves. These three sets of structures are divided from each other by two processes of the dura mater. The junction of the inferior petrosal sinus with the internal jugular vein takes place on the lateral aspect of the nerves.

The **basilar plexus** (fig. 670) consists of several interlacing venous channels between the layers of the dura mater over the basilar part of the occipital bone; it connects the two inferior petrosal sinuses, and communicates with the anterior internal vertebral venous plexus.

Middle meningeal veins.—The middle meningeal veins accompany the branches of the middle meningeal arteries, but, like the cranial blood-sinuses, they consist of channels in the dura mater and their walls are devoid of muscular tissue. They should therefore be termed the *middle meningeal sinuses*.

They communicate above with the superior sagittal sinus and adjoining venous lacunæ, and unite to form two principal trunks, an anterior and a posterior, which accompany more or less closely the branches of the middle meningeal arteries in the grooves on the inner surface of the parietal bone; sometimes they occupy grooves apart from the arteries.* Their mode of ending is subject to some variation. The two trunks may leave the cranial cavity through the foramen spinosum and open into the pterygoid venous plexus, or may join to form a single vessel before passing through the foramen. The anterior trunk may reach the pterygoid plexus by emerging through the foramen ovale, or it may end in the sphenoparietal sinus or in the cavernous sinus. Besides their meningeal tributaries they receive some small inferior cerebral veins, and communicate with the diploic veins and with the middle cerebral vein.

Emissary veins.—The emissary veins pass through apertures in the cranial wall and establish communications between the venous sinuses inside the skull and the veins external to it. Some are always present, others occasionally so. The principal emissary veins are the following. 1. A mastoid vein runs through the mastoid foramen and unites the transverse sinus with the posterior auricular or occipital vein. 2. A parietal vein passes through the parietal foramen and connects the superior sagittal sinus with the veins of the scalp. 3. A network of minute veins (rete canalis hypoglossi) traverses the hypoglossal canal and joins the transverse

* Wood Jones (*Journal of Anatomy and Physiology*, vol. xlv.) has pointed out that the grooves on the inner surfaces of the parietal bones are in reality impressed by the middle meningeal sinuses and not by the middle meningeal arteries, and says 'that, contrary to the general belief of surgeons, the vascular tunnel at the pterion, although it lodges arterial branches, is typically formed by, and typically lodges a venous sinus.' He finds that veins do not commonly pass out of the skull through the foramen spinosum, but adds that the limited number of his dissections for determining this point does not warrant any dogmatic statement. He is inclined to think that the blood which is poured out in most cases of middle meningeal hæmorrhage may be derived from the easily torn sinuses. A similar view is expressed in Poirier and Charpy's *Traité of Human Anatomy*, vol. ii. part 3, p. 930.

sinus with the vertebral vein and deep veins of the neck. 4. An inconstant condyloid vein passes through the condyloid canal and connects the transverse sinus with the deep veins of the neck. 5. A network of veins (*rete foraminis ovalis*) unites the cavernous sinus with the pterygoid plexus through the foramen ovale. 6. Two or three small veins run through the foramen lacerum and connect the cavernous sinus with the pterygoid plexus. 7. A vein traverses the foramen of Vesalius and connects the same parts. 8. An internal carotid plexus of veins accompanies the internal carotid artery through the carotid canal of the temporal bone and unites the cavernous sinus with the internal jugular vein. 9. A vein passes through the foramen cæcum and connects the veins of the nasal cavity with the superior sagittal sinus.

Applied Anatomy.—These emissary veins are of importance in surgery. Inflammatory processes commencing on the outside of the skull may travel inwards through them, and lead to osteophlebitis of the diploë and inflammation of the membranes of the brain. To this in former days was to be attributed one of the principal dangers of wounds of the scalp.

By means of these emissary veins blood may be abstracted from the intracranial circulation—e.g. leeches applied behind the ear drain blood from the transverse sinus through the mastoid vein. Again, epistaxis in children may relieve severe headache, the blood which flows from the nose being partly derived from the superior sagittal sinus by means of the vein passing through the foramen cæcum.

VEINS OF THE UPPER EXTREMITY AND THORAX

The veins of the upper extremity are divided into two sets, *superficial* and *deep*, which anastomose frequently with each other. The superficial veins are placed beneath the skin, in the superficial fascia; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial veins.

SUPERFICIAL VEINS OF UPPER EXTREMITY

The *superficial veins* of the upper extremity are the cephalic, basilic, and median antibrachial veins, and their tributaries.

The *dorsal digital veins* pass along the sides of the fingers and are joined to one another by oblique communicating branches. Those from the adjacent sides of the fingers unite to form three *dorsal metacarpal veins* (fig. 673), which end in a *dorsal venous network* opposite the middle of the metacarpus. The radial part of the network is joined by the dorsal digital vein from the radial side of the index finger and by the dorsal digital veins of the thumb, and is prolonged upwards as the cephalic vein. The ulnar part of the network receives the dorsal digital vein of the ulnar side of the little finger and is continued upwards as the basilic vein. A communicating branch frequently connects the dorsal venous network with the cephalic vein about the middle of the forearm.

The *proper volar digital veins* are connected to the dorsal digital veins by oblique *intercapitular veins* which pass backwards between the heads of the metacarpal bones. They also drain into a venous plexus which is situated over the thenar and hypothenar eminences and across the front of the palm.

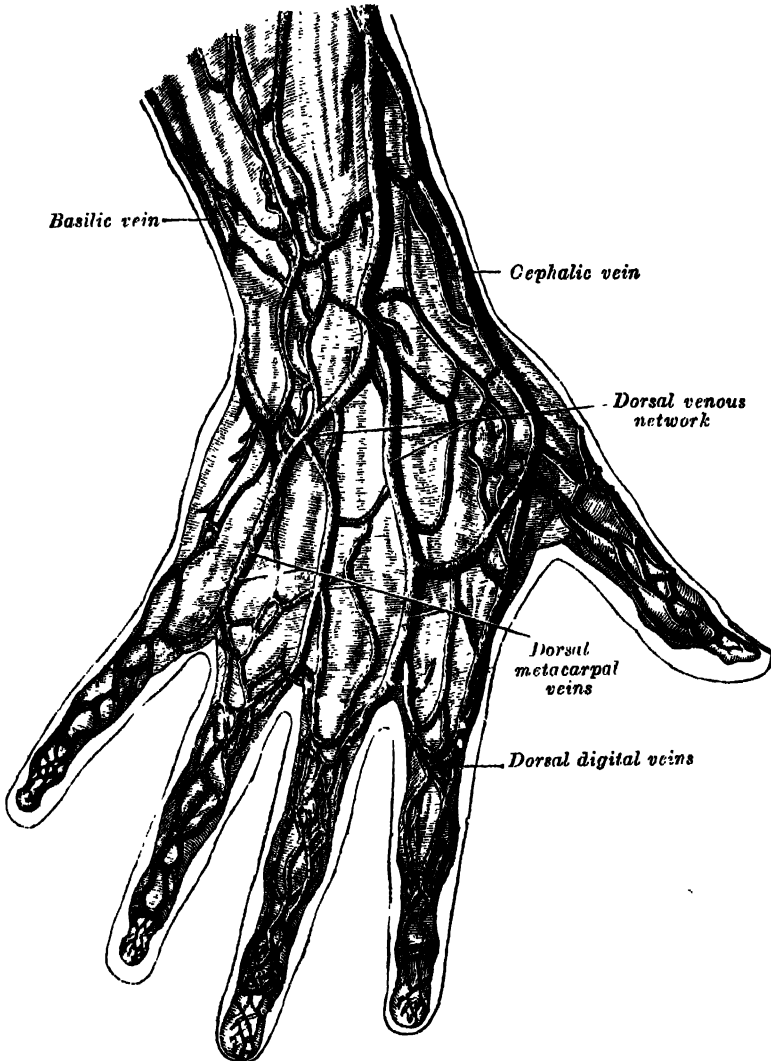
The *cephalic vein* (fig. 674) begins in the radial part of the dorsal venous network of the hand and winds upwards round the radial border of the forearm to its volar surface, receiving tributaries from both surfaces. Below the front of the elbow it gives off the *median cubital vein* (median basilic vein), which receives a communicating branch from the deep veins of the forearm and passes medialwards to join the basilic vein. The cephalic vein then ascends in front of the elbow in the groove between the Brachioradialis and the Biceps brachii. It crosses superficially to the musculocutaneous nerve and runs upwards along the lateral border of the Biceps brachii. In the upper third of the arm it passes between the Pectoralis major and Deltoideus, where it is accompanied by the deltoid branch of the thoraco-acromial artery. It pierces the coracoclavicular fascia, crosses the axillary artery, and ends in the axillary vein just below the

clavicle. Sometimes it communicates with the external jugular vein by a branch which ascends in front of the clavicle.

In some cases the median cubital vein is large and carries all or most of the blood from the cephalic into the basilic vein, the result being that the proximal half of the cephalic vein is either absent or of small size.

The *accessory cephalic vein* arises from a small tributary plexus on the back of the forearm or from the ulnar side of the dorsal venous network; it joins

FIG. 673. --The veins on the dorsum of the hand. (Bourguery.)



the cephalic below the elbow. In some cases it springs from the cephalic vein above the wrist and joins it again higher up. A large oblique branch frequently connects the basilic and cephalic veins on the back of the forearm.

The *basilic vein* (fig. 674) begins in the ulnar part of the dorsal venous network of the hand. It runs up for some distance on the posterior surface of the ulnar side of the forearm but inclines forward to the anterior surface below the elbow. It is joined by the median cubital vein, and ascends obliquely in the groove between the Biceps brachii and Pronator teres; filaments of the medial antibrachial cutaneous nerve pass both in front of and behind this portion of the vein. It then runs upwards along the medial border of the Biceps brachii, perforates the deep fascia a little below the middle of the arm,

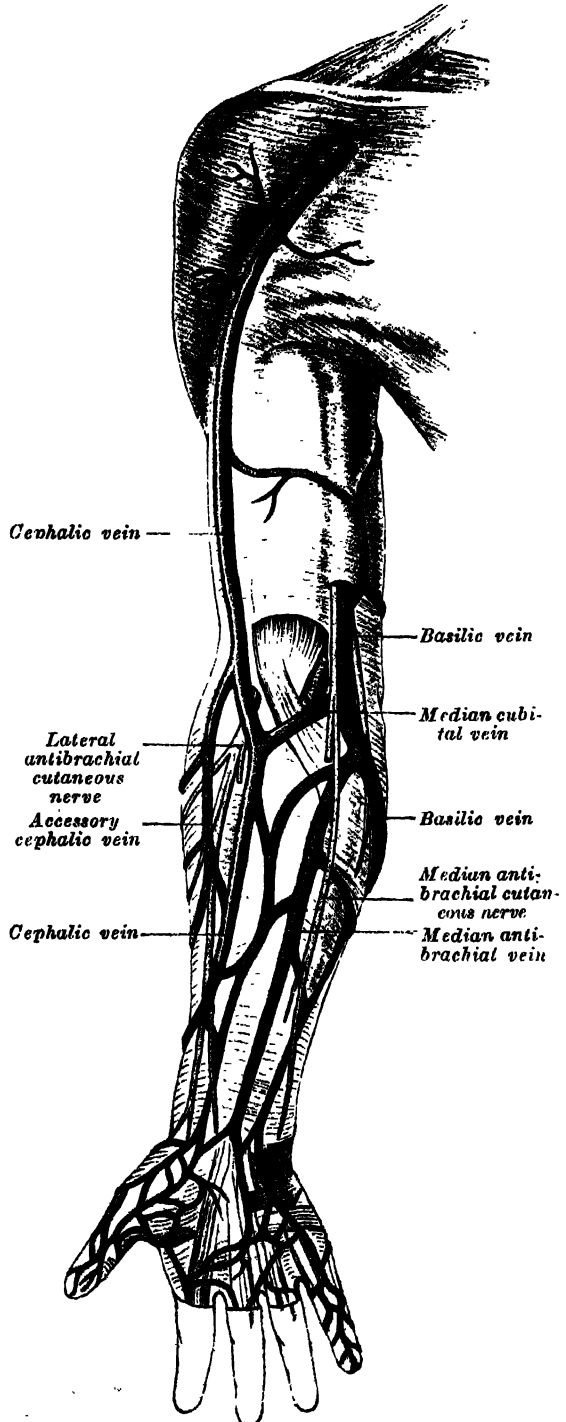
and, ascending on the medial side of the brachial artery to the lower border of the *Teres major*, is continued onwards as the axillary vein.

The median antibrachial vein drains the venous plexus on the volar surface of the hand. It ascends on the front of the forearm and ends in the basilic or median cubital vein; in a small proportion of cases it divides below the elbow into two branches, one of which joins the basilic, the other the cephalic.

FIG. 674.—The superficial veins of the upper extremity.

Applied Anatomy.—*Venesec-tion* is generally performed at the bend of the elbow, and as a matter of practice the largest vein in this situation, the median cubital (median basilic), is commonly selected. The advantages of selecting this vein are, that in addition to its being the largest vessel and therefore yielding a greater supply of blood, it is the least movable and can be easily steadied on the *lacertus fibrosus* (bicipital fascia) on which it rests. The disadvantage is, that it is in close relationship with the brachial artery, separated only by the *lacertus fibrosus*; formerly, when venesection was frequently practised, arteriovenous aneurysm was no uncommon result.

Intravenous infusion of normal saline solution is frequently required in modern surgery for conditions of severe shock and after profuse hemorrhages, and has superseded the older method of transfusion of blood. The patient's arm is surrounded by a tight bandage so as to impede the venous return, and a small incision is made over the largest vein visible in front of the elbow; a double ligature is now passed around the vein, and the lower one is tied; the vein is then opened and a cannula, connected with a funnel by tubing, is inserted. The bandage is next removed from the arm, and two, three, or more pints of hot saline solution are allowed to flow into the vein; when a sufficient quantity has gone in, the upper ligature round the vein is tied and a stitch put in the skin wound.



DEEP VEINS OF UPPER EXTREMITY

The deep veins follow the course of the arteries, and form their *venae comitantes*. They are generally arranged in pairs, and are

situated one on either side of the corresponding artery, and connected at intervals by short transverse branches.

Deep veins of the hand.—The superficial and deep volar arterial arches are each accompanied by a pair of venæ comitantes which constitute respectively the *superficial* and *deep volar venous arches*, and receive the veins corresponding to the branches of the arterial arches; thus the *common volar digital veins*, formed by the union of the *proper volar digital veins*, open into the superficial, and the *volar metacarpal veins* into the deep volar venous arches. The deep veins accompanying the dorsal metacarpal arteries receive perforating branches from the volar metacarpal veins, and end in the radial veins and in the dorsal venous network.

The deep veins of the forearm are the venæ comitantes of the radial and ulnar veins and constitute respectively the upward continuations of the deep and superficial volar venous arches; they unite in front of the elbow to form the brachial veins. The radial veins are smaller than the ulnar, and receive the deep veins of the dorsum of the hand. The ulnar veins receive tributaries from the deep volar venous arches and communicate with the superficial veins at the wrist; near the elbow they receive the volar and dorsal interosseous veins and send a large communicating branch (*profunda vein*) to the median cubital vein.

The brachial veins are placed one on either side of the brachial artery, and receive tributaries corresponding with the branches of that artery; near the lower margin of the Subscapularis, they join the axillary vein; the medial one frequently joins the basilic vein.

These deep veins have numerous anastomoses, not only with each other, but also with the superficial veins.

The axillary vein begins at the lower border of the Teres major, as the continuation of the basilic vein, increases in size as it ascends, and ends at the outer border of the first rib as the subclavian vein. Near the lower border of the Subscapularis it receives the brachial veins and, close to its termination, the cephalic vein; its other tributaries correspond with the branches of the axillary artery. It lies on the medial side of the axillary artery, which it partly overlaps; between the two vessels are the medial cord of the brachial plexus, the ulnar and the medial anterior thoracic nerves. It is provided with a pair of valves opposite the lower border of the Subscapularis; valves are also found at the ends of the cephalic and subscapular veins.

Applied Anatomy.—Since the axillary vein is superficial to and larger than the axillary artery, which it overlaps, it is more liable to be wounded than the artery in the operation of extirpation of the axillary glands, especially as these glands, when diseased, are apt to become adherent to it. When it is wounded, there is always a danger of air being drawn into it, and death resulting. To avoid wounding it in extirpating the axillary glands, it is advisable to expose the vein as soon as possible; no sharp cutting instruments should be used after the axillary cavity has been freely exposed; and care should be taken to use no undue force in isolating the glands (p. 613). Should the vein be so imbedded in a malignant deposit that the latter cannot be removed without taking away a part of the vein, this must be done after the vessel has been ligatured above and below.

The subclavian vein, the continuation of the axillary vein, extends from the outer border of the first rib to the sternal end of the clavicle, where it unites with the internal jugular vein to form the innominate vein. It is in relation, in front, with the clavicle and Subclavius; behind and above, with the subclavian artery, from which it is separated medially by the Scalenus anterior and the phrenic nerve. Below, it rests in a depression on the first rib and upon the pleura. It is usually provided with a pair of valves, which are situated about 2.5 cm. from its termination.

Its tributaries are the external jugular vein, sometimes the anterior jugular vein, and occasionally a small branch, which ascends in front of the clavicle, from the cephalic vein.

At its angle of junction with the internal jugular vein, the left subclavian vein receives the thoracic duct, and the right subclavian vein the right lymphatic duct.

VEINS OF THE THORAX (fig. 675)

The **innominate veins** are two large trunks, placed one on either side of the root of the neck, and formed by the union of the internal jugular and subclavian veins of the corresponding side; they are devoid of valves.

The **right innominate vein**, about 2.5 cm. long, begins behind the sternal end of the right clavicle, and, passing almost vertically downwards, joins the left innominate vein behind the cartilage of the first rib, close to the right border of the sternum, to form the superior vena cava. It lies in front and to the right of the innominate artery; on its right side are the right phrenic nerve and the right pleura, which are interposed between it and the apex of the lung; behind and to its left is the right vagus nerve.

Its tributaries are the right vertebral, the right internal mammary and the right inferior thyroid veins, and sometimes the first right intercostal vein.

The **left innominate vein**, about 6 cm. long, begins behind the sternal end of the left clavicle and runs obliquely downwards and to the right behind the upper half of the manubrium sterni to the sternal end of the first right costal cartilage, where it unites with the right innominate vein to form the superior vena cava. It is separated from the manubrium sterni by the Sternohyoideus and Sternothyroideus, the thymus or its remains, and some loose areolar tissue. Behind it are the innominate, left common carotid, and left subclavian arteries, together with the left vagus and phrenic nerves. The left innominate vein may occupy a higher level, crossing the jugular notch and lying directly in front of the trachea.

Its tributaries are the left vertebral, left internal mammary, left inferior thyroid, and left superior intercostal veins, sometimes the first left intercostal vein and occasionally some thymic and pericardial vein.

Peculiarities.—Sometimes the innominate veins open separately into the right atrium; in such cases the right vein takes the ordinary course of the superior vena cava; the left vein—*left superior vena cava*, as it is then termed—which may communicate by a small branch with the right one, passes in front of the root of the left lung, and, turning to the back of the heart, ends in the right atrium. This occasional condition in the adult is due to the persistence of the early fetal condition, and is the normal state of things in birds and some mammals.

The **internal mammary veins** are *venæ comitantes* to the lower half of the internal mammary artery, and receive tributaries corresponding to the branches of the artery. They unite to form a single trunk, which runs up on the medial side of the artery and ends in the corresponding innominate vein. The *superior phrenic vein* (i.e. the vein accompanying the pericardiophrenic artery) usually opens into the internal mammary vein.

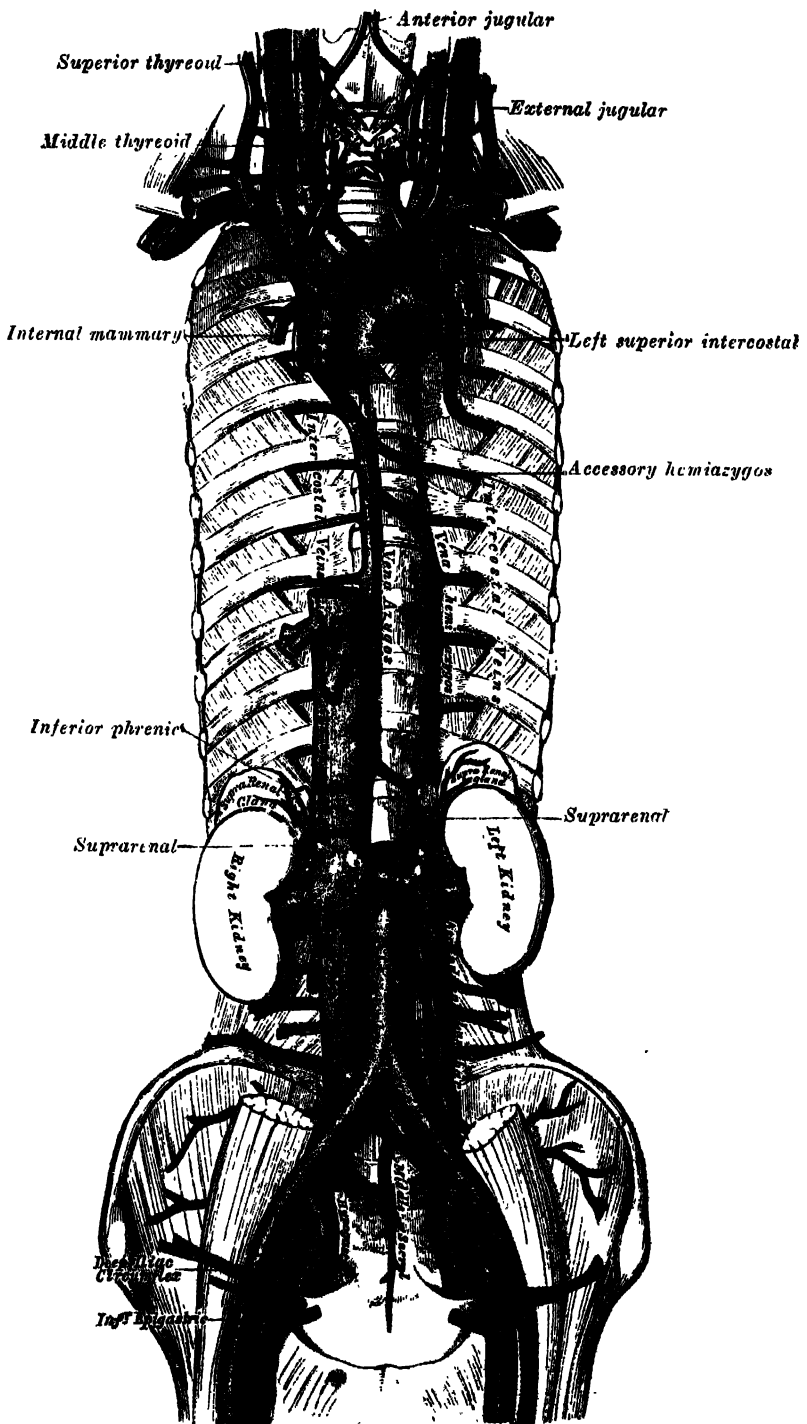
The **inferior thyroid veins**, two or more in number, arise in the thyroid gland in a venous network which communicates with the middle and superior thyroid veins. They form a plexus in front of the trachea, behind the Sternothyroideus. From this plexus a left vein descends and joins the left innominate trunk, and a right vein passes obliquely downwards and to the right across the innominate artery to open into the right innominate vein, at its junction with the superior vena cava; frequently the right and left veins open by a common trunk in the latter situation. These veins receive œsophageal, tracheal, and inferior laryngeal veins, and are provided with valves at their terminations.

The **left superior intercostal vein** receives the second and third (and sometimes the fourth) left intercostal veins; it runs obliquely upwards and forwards on the left side of the aortic arch between the left phrenic and vagus nerves and opens into the left innominate vein. It usually receives the left bronchial veins, and sometimes the left superior phrenic vein; it communicates below with the accessory hemiazygos vein.

The **superior vena cava** drains the blood from the upper half of the body. It measures about 7 cm. in length, is formed by the junction of the two innominate veins, and is devoid of valves. It begins behind the cartilage of the right first rib close to the sternum, and, descending vertically behind the first and second intercostal spaces, ends in the upper part of the right atrium opposite the upper border of the third right costal cartilage; the lower half of the

vessel is within the pericardium. In its course it describes a slight curve, the convexity of which is to the right side.

FIG. 675.—The venæ cavæ and the azygos vein, with their tributaries.



Relations.—In front of the superior vena cava are the anterior margins of the right lung and pleura with the pericardium intervening below; these separate it

from the first and second intercostal spaces, and from the second and third right costal cartilages; *behind* it are the root of the right lung and the right vagus nerve. On its *right side* are the phrenic nerve and right pleura; on its *left side*, the commencement of the innominate artery and the ascending aorta, the latter overlapping it. The portion contained within the pericardium is covered, in front and laterally, by the serous pericardium.

Tributaries.—Before it pierces the pericardium, the superior vena cava receives the azygos vein and several small veins from the pericardium and other contents of the mediastinal cavity.

The **azygos vein** begins opposite the first or second lumbar vertebra, as a branch of the right ascending lumbar vein (p. 702); sometimes as a branch of the right renal vein, or of the inferior vena cava. It enters the thorax through the aortic hiatus in the Diaphragm, and ascends along the right side of the vertebral column to the fourth thoracic vertebra, where it arches forward over the root of the right lung, and ends in the superior vena cava, just before that vessel pierces the pericardium. In the aortic hiatus it lies with the thoracic duct on the right side of the aorta; in the thorax it lies upon the intercostal arteries, on the right side of the aorta and thoracic duct, and is partly covered by pleura.

Tributaries.—It receives the right subcostal and intercostal veins with the exception of the vein from the first intercostal space; the veins from the second, third and fourth intercostal spaces open by a common stem called the right superior intercostal vein. It also receives the hemiazygos and accessory hemiazygos veins, several oesophageal, mediastinal, and pericardial veins, and, near its termination, the right bronchial veins. A few imperfect valves are found in the azygos vein; but its tributaries are provided with complete valves.

The **hemiazygos vein** begins in the left ascending lumbar vein or in the left renal vein. It enters the thorax through the left crus of the Diaphragm, and, ascending on the left side of the vertebral column as high as the eighth thoracic vertebra, passes across the column, behind the aorta, oesophagus, and thoracic duct, to end in the azygos vein. It receives the lower three intercostal veins and the subcostal vein of the left side, and some oesophageal and mediastinal veins.

The **accessory hemiazygos vein** descends on the left side of the vertebral column. It receives the veins from the fourth (or fifth) to the eighth intercostal spaces inclusive, and sometimes the left bronchial veins. It crosses the body of the seventh thoracic vertebra and joins the azygos vein.

The **intercostal veins** are sometimes named the *posterior intercostal veins* to distinguish them from the small *anterior intercostal veins* which are tributaries of the musculophrenic and internal mammary veins. They run alongside the anterior rami of the intercostal arteries and are eleven in number on either side. As they approach the vertebral column each receives a tributary corresponding with the posterior ramus of an intercostal artery, and returning blood from the muscles and skin of the back and from the vertebral venous plexuses.

On *both* sides of the thorax the first intercostal vein ascends in front of the neck of the first rib and ends in the corresponding innominate or vertebral vein.

On the right side the second, third and fourth intercostal veins unite to form the *right superior intercostal vein*, which joins the terminal part of the azygos vein. The veins from the intercostal spaces below the fourth open separately into the vena azygos.

On the left side the second and third (and sometimes the fourth) intercostal veins unite to form the left superior intercostal vein (p. 691). The veins from the fourth (or fifth) to the eighth intercostal spaces inclusive end in the accessory hemiazygos vein, and the veins from the lower three spaces in the hemiazygos vein.

Applied Anatomy.—In obstruction of the superior vena cava, the azygos and hemiazygos veins are one of the principal means by which the venous circulation is carried on, connecting as they do the superior and inferior vena cavae, and communicating with the common iliac veins by the ascending lumbar veins, and with many of the tributaries of the inferior vena cava.

Thrombosis of the superior vena cava is oftenest due to pressure exerted on the vessel by an aneurysm or a tumour; it may also occur by propagation of clotting from a tributary peripheral vein. If occlusion of the vessel take place slowly, a collateral venous circulation may be established; the patient will have some cedema with dilation and

congestion of the veins about the head and neck, and may also suffer from attacks of dyspnoea and recurrent pleural effusion. In most cases, however, the blockage of the superior cava takes place rapidly, and is rapidly fatal.

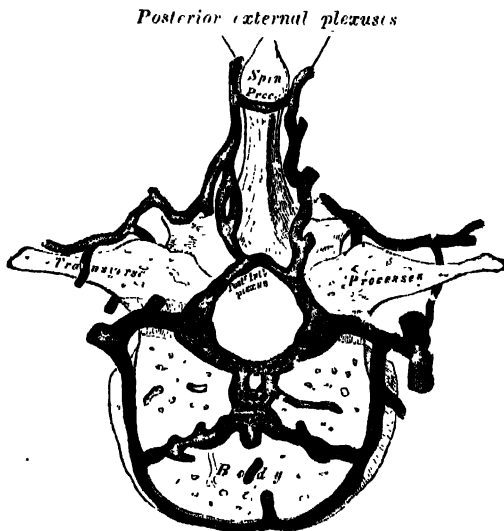
The **bronchial veins**, usually two on either side, return the blood from the larger bronchi, and from the structures at the roots of the lungs; those of the right side open into the terminal part of the vena azygos; those of the left side, into the left superior intercostal vein or the accessory hemiazygos vein. Some of the blood carried to the lungs through the bronchial arteries is returned to the heart through the pulmonary veins.

VEINS OF THE VERTEBRAL COLUMN (figs. 676, 677)

The veins which drain the blood from the vertebral column, the neighbouring muscles, and the meninges of the medulla spinalis form intricate plexuses extending along the entire length of the column; these plexuses are divisible into two groups, external and internal, according to their positions outside or inside the vertebral canal. The plexuses of the two groups anastomose freely with each other, and end in the intervertebral veins.

The **external vertebral venous plexuses**, best marked in the cervical region, consist of anterior and posterior plexuses which anastomose freely with each other.

FIG. 676.—Transverse section of a thoracic vertebra, showing the vertebral venous plexuses.



The **anterior external plexuses** lie in front of the bodies of the vertebrae, communicate with the basivertebral and intervertebral veins, and receive tributaries from the vertebral bodies. The **posterior external plexuses** are placed partly on the posterior surfaces of the vertebral arches and their processes, and partly between the deep dorsal muscles. In the cervical region they anastomose with the vertebral, occipital, and deep cervical veins.

The **internal vertebral venous plexuses** lie within the vertebral canal between the dura mater and the vertebrae, and receive tributaries from the bones and from the medulla spinalis. They form a closer network than the external plexuses, and, running mainly in a vertical direction, form four longitudinal veins, two

in front and two behind; they therefore may be divided into anterior and posterior groups. The **anterior internal plexuses** consist of large veins which lie on the posterior surfaces of the vertebral bodies and intervertebral fibrocartilages, on either side of the posterior longitudinal ligament; under cover of this ligament they are connected by transverse branches into which the basivertebral veins open. The **posterior internal plexuses** are placed one on either side of the middle line in front of the vertebral arches and ligamenta flava, and anastomose, by veins passing through those ligaments, with the posterior external plexuses.

The anterior and posterior plexuses communicate freely with one another by a series of venous rings, one opposite each vertebra. Around the foramen magnum they form an intricate network which opens into the vertebral veins and is connected above with the occipital sinus, the basilar plexus, the condyloid emissary vein, and the rete canalis hypoglossi.

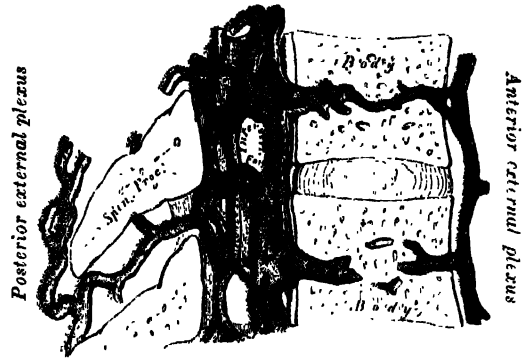
The **basivertebral veins** emerge from the foramina on the posterior surfaces of the vertebral bodies. They are contained in large, tortuous channels in the substance of the bones, similar in every respect to those found in the diploë of

the cranial bones. They communicate through small openings on the front and sides of the bodies of the vertebræ with the anterior external vertebral plexuses, and converge behind to form single (sometimes double) veins which open by valved orifices into the transverse branches uniting the anterior internal vertebral plexuses. The basivertebral veins become greatly enlarged in advanced age.

FIG. 677.—Median sagittal section of two thoracic vertebræ, showing the vertebral venous plexuses.

The **intervertebral veins** accompany the spinal nerves through the intervertebral foramina; they receive the veins from the medulla spinalis, drain the internal and external vertebral plexuses and end in the vertebral, intercostal, lumbar, and lateral sacral veins, their orifices being provided with valves.

The **veins of the medulla spinalis** are situated in the pia mater and form a tortuous, venous plexus. In this plexus there are: (1) two median longitudinal veins, one in front of the anterior fissure, and the other behind the posterior sulcus of the medulla spinalis; and (2) four lateral longitudinal veins which run behind the nerve-roots. They end in the internal vertebral venous plexuses. Near the base of the skull they unite to form two or three small trunks, which communicate with the vertebral veins, and end in the inferior cerebellar veins, or in the inferior petrosal sinuses.



VEINS OF THE LOWER EXTREMITY, ABDOMEN, AND PELVIS

The veins of the lower extremity are subdivided, like those of the upper extremity, into two sets, superficial and deep: the superficial veins are placed beneath the skin in the superficial fascia; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial set. Valves are more numerous in the veins of the lower than in those of the upper extremity.

1. SUPERFICIAL VEINS OF LOWER EXTREMITY

The **superficial veins** of the lower extremity are the great and small saphenous veins and their tributaries.

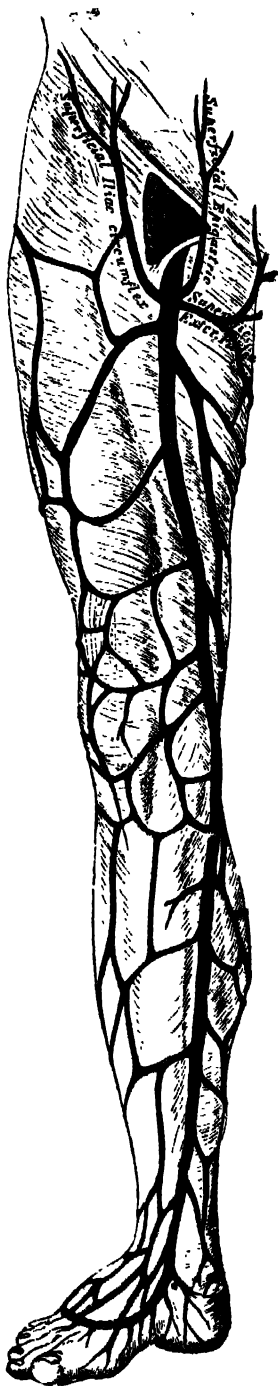
The **dorsal digital veins** receive, in the clefts between the toes, the *intercapitular veins* from the plantar digital veins, and then join to form *dorsal metatarsal veins*, which unite across the distal ends of the metatarsal bones in a *dorsal venous arch*. Proximal to this arch is an irregular venous network which receives tributaries from the deep veins and is joined at the sides of the foot by a *medial* and a *lateral marginal vein*, formed mainly by the union of veins from the superficial parts of the sole of the foot.

On the sole of the foot the superficial veins form a *plantar cutaneous venous arch*, which extends across the roots of the toes and opens at the sides of the foot into the medial and lateral marginal veins. Proximal to this arch is a *plantar cutaneous venous network* which is especially dense in the fat beneath the heel; this network communicates with the plantar cutaneous venous arch and with the deep veins, but is chiefly drained into the medial and lateral marginal veins.

The **great saphenous vein** (fig. 678), the longest vein in the body, begins in the medial marginal vein of the foot and ends in the femoral vein about 3 cm. below the inguinal ligament. It ascends in front of the tibial malleolus and along the medial side of the leg in relation with the saphenous nerve. It

runs upwards behind the medial condyles of the tibia and femur and along the medial side of the thigh and, passing through the fossa ovalis, ends in the femoral vein. The valves in the great saphenous vein vary from ten to twenty in number; they are more numerous in the leg than in the thigh.

FIG. 678.—The great saphenous vein and its tributaries.



Tributaries.—At the ankle it receives veins from the sole of the foot through the medial marginal vein; in the leg it communicates freely with the small saphenous vein and with the anterior and posterior tibial veins, and receives many cutaneous veins; in the thigh it communicates with the femoral vein and receives numerous tributaries; those from the medial and posterior parts of the thigh frequently unite to form a large *accessory saphenous vein* which joins the main vein at a variable level. Near the fossa ovalis (fig. 679) it is joined by the superficial epigastric, superficial iliac circumflex, and superficial external pudendal veins. The superficial epigastric and superficial iliac circumflex veins drain the lower part of the abdominal wall, the latter vein also receiving tributaries from the upper and lateral parts of the thigh; the superficial external pudendal vein drains part of the scrotum and receives the superficial dorsal vein of the penis.

A vein, named the *thoraco-epigastric*, runs along the lateral wall of the trunk, connecting the superficial epigastric with the lateral thoracic veins and thus establishing an important communication between the femoral and axillary veins.

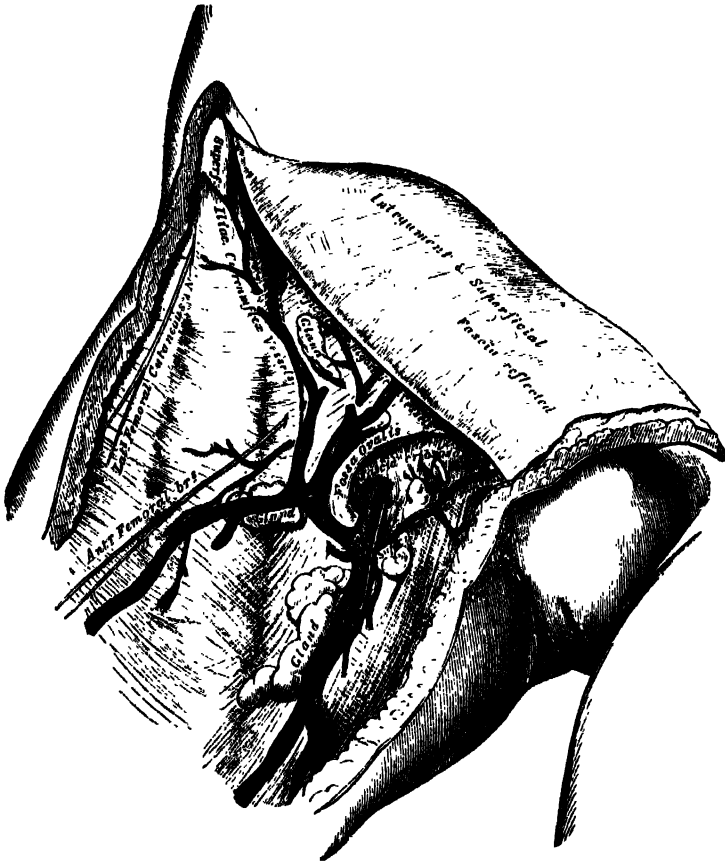
The *small saphenous vein* (fig. 680) begins behind the lateral malleolus as a continuation of the lateral marginal vein; it first ascends along the lateral margin of the tendo calcaneus, and then crosses it obliquely to reach the middle of the back of the leg. Running upwards, it perforates the deep fascia in the lower part of the popliteal fossa, and ends in the popliteal vein, between the heads of the Gastrocnemius. It communicates with the deep veins on the dorsum of the foot, and receives numerous large tributaries from the back of the leg. Before it pierces the deep fascia, it gives off a branch which runs upwards and forwards to join the great saphenous vein; this branch is sometimes large, and may then form the direct continuation of the small saphenous vein. In the lower third of the leg the vein is in close relation with

the sural nerve, in the upper two-thirds with the medial sural cutaneous nerve.

The small saphenous vein possesses from nine to twelve valves, one of which is found near its termination in the popliteal vein.

Applied Anatomy.—A varicose condition is more frequently met with in the saphenous veins than in the other veins of the body, except perhaps the testicular and hæmorrhoidal veins. The main cause of this is the high blood-pressure, determined chiefly by the erect position; and the length of the column of blood, which has to be propelled in an uphill direction. In normal vessels there is only just sufficient force to perform this task; and in those cases where there is diminished resistance of the walls of the veins, these vessels are liable to dilate and a varicose condition is set up. This diminished resistance may be due to heredity, the vein-walls being congenitally weak, or may follow inflammatory conditions of the vessels. Increased blood-pressure in the veins, caused by any obstacle to the return of the venous blood, such as the pressure of a tumour, or the gravid uterus, or tight gartering, may also produce varix. In the normal condition of the veins, the valves in their interior break up the column of blood into a number of smaller columns,

FIG. 679.—The great saphenous vein and its tributaries at the fossa ovalis.



and so to a considerable extent mitigate the ill effects of the erect position; but when the dilatation of the veins has reached a certain limit, the valves become incapable of supporting the overlying column of blood, and the pressure is increased, tending to emphasise also the varicose condition. Both the saphenous veins in the leg are accompanied by nerves, the great saphenous being joined by its companion nerve just below the level of the knee-joint; no doubt much of the pain of varicose veins in the leg is due to this fact.

Operations for the relief of varicose veins are frequently required, portions of the veins being removed after having been ligatured above and below. It is important to note whether the main varicose area drains into the great or the small saphenous vein—the former condition being much the more common—and to control the venous return by removing a small portion of the main trunk just before it opens into the deep vein by passing through the deep fascia; thus in most cases a piece should be removed from the great saphenous just before it passes through the fossa ovalis (saphenous opening), and in addition the affected veins should be excised just above and below the level of the knee-joint. In other cases the small saphenous will have to be dealt with immediately below the point where it pierces the fascial roof of the popliteal fossa.

DEEP VEINS OF LOWER EXTREMITY

The deep veins of the lower extremity accompany the arteries and their branches; they possess numerous valves.

The plantar digital veins arise from plexuses on the plantar surfaces of the digits, and, after sending *intercapitular veins* to join the dorsal digital veins, unite to form four *plantar metatarsal veins*; these run backwards in the metatarsal spaces, communicate, by means of perforating veins, with the veins on the dorsum of the foot, and unite to form the *deep plantar venous arch* which lies alongside the plantar arterial arch. From the deep plantar venous arch the *medial* and *lateral plantar veins* run backwards close to the corresponding arteries and, after communicating with the great and small saphenous veins, unite behind the medial malleolus to form the posterior tibial veins.

The posterior tibial veins accompany the posterior tibial artery, and are joined by the *peroneal veins*.

The anterior tibial veins are the upward continuations of the *venæ comitantes* of the *dorsalis pedis* artery. They leave the front of the leg by passing between the tibia and fibula, through the upper part of the crural interosseous membrane, and unite with the posterior tibial veins to form the *popliteal vein*.

The popliteal vein, formed by the junction of the anterior and posterior tibial veins at the lower border of the Popliteus, ascends through the popliteal fossa to the aperture in the Adductor magnus, where it becomes the femoral vein. In the lower part of its course it is medial to the artery; between the heads of the Gastrocnemius it is superficial to it; above the knee-joint, it is lateral to it. Its tributaries are the small saphenous vein and the veins corresponding to the branches of the popliteal artery. There are usually four valves in the popliteal vein.

The femoral vein accompanies the femoral artery through the upper two-thirds of the thigh. In the lower part of its course it is lateral to the artery; higher up, it is behind it; at the inguinal ligament, it is medial to it. It receives numerous muscular tributaries, and about 4 cm. below the inguinal ligament is joined by the *vena profunda femoris*; near its termination it is joined by the great saphenous vein. It contains three valves.

The *vena profunda femoris* lies superficial to the corresponding artery; it receives tributaries corresponding to the muscular and perforating branches of the *arteria profunda femoris*, and through these establishes communications with the popliteal vein below and the inferior gluteal vein above. It also receives the medial and lateral femoral circumflex veins.

VEINS OF ABDOMEN AND PELVIS (fig. 681)

The external iliac vein, the upward continuation of the femoral vein, begins behind the inguinal ligament, and ascends along the brim of the lesser pelvis, to a point opposite the sacro-iliac articulation, where it unites with the hypogastric vein to form the common iliac vein. On the right side, it lies at first medial to the artery; but, as it passes upwards, gradually inclines behind it. On the left side, it lies altogether on the medial side of the artery. It frequently contains one, sometimes two, valves.

Tributaries.—It receives the inferior epigastric, deep iliac circumflex, and pubic veins.

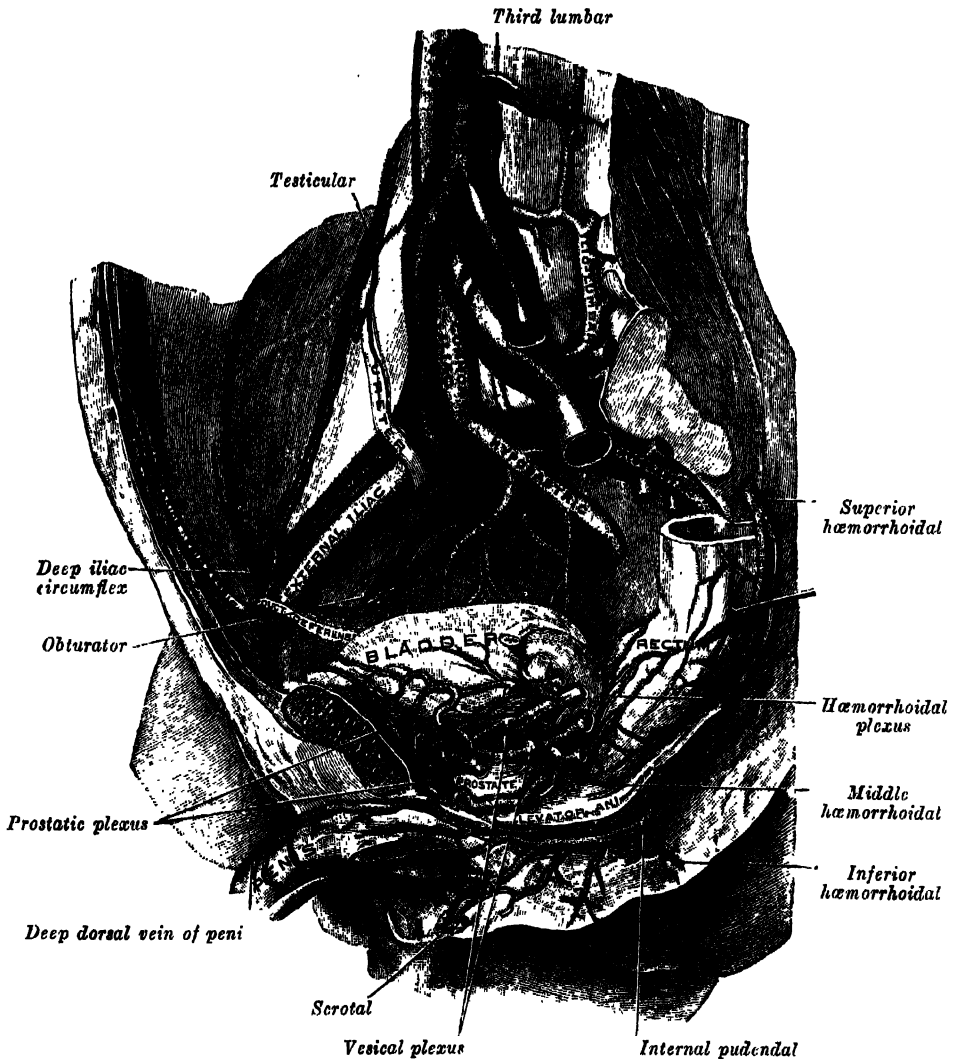
FIG. 680.—The small saphenous vein.



The **inferior epigastric vein** is formed by the union of the *venæ comitantes* of the inferior epigastric artery, which communicate above with the superior epigastric vein; it joins the external iliac vein about 1.25 cm. above the inguinal ligament.

The **deep iliac circumflex vein** is formed by the union of the *venæ comitantes* of the deep iliac circumflex artery, and joins the external iliac vein about 2 cm. above the inguinal ligament.

FIG. 681.—The veins of the right half of the male pelvis. (Spalteholz.)



The **pubic vein** communicates with the obturator vein in the obturator foramen, ascends on the back of the os pubis alongside the pubic branch of the inferior epigastric artery and ends in the external iliac vein.

The **hypogastric or internal iliac vein** begins near the upper part of the greater sciatic foramen, ascends behind and slightly medial to the hypogastric artery, and, at the brim of the pelvis, joins with the external iliac vein to form the common iliac vein.

Tributaries.—With the exception of the foetal umbilical vein, which passes upwards and backwards from the umbilicus to the liver, and the ilio-lumbar vein, which usually joins the common iliac vein, the tributaries of the hypogastric vein correspond with the branches of the hypogastric artery. It receives (a) the glutæal, internal pudendal, and obturator veins, which have their origins outside the pelvis;

(b) the lateral sacral veins, which lie in front of the sacrum; and (c) the middle hæmorrhoidal, the vesical, uterine, and vaginal veins, which originate in venous plexuses connected with the pelvic viscera.

1. The **superior gluteal veins** (gluteal veins) are the *venæ comitantes* of the superior gluteal artery; they receive tributaries from the buttock corresponding with the branches of the artery, enter the pelvis through the greater sciatic foramen, above the Piriformis, and end in the hypogastric vein; they frequently unite to form a single trunk before ending in this vein.

2. The **inferior gluteal veins** (sciatic veins) are the *venæ comitantes* of the inferior gluteal artery; they begin on the upper part of the back of the thigh, where they anastomose with the medial femoral circumflex and first perforating veins; they enter the pelvis through the lower part of the greater sciatic foramen and join to form a stem which opens into the lower part of the hypogastric vein.

3. The **internal pudendal veins** (internal pudic veins) are the *venæ comitantes* of the internal pudendal artery. They begin in the deep veins of the penis, which issue from the corpus cavernosum penis, accompany the internal pudendal artery, and unite to form a single vessel, which ends in the hypogastric vein. They receive the veins from the urethral bulb, and the perinæal and inferior hæmorrhoidal veins. The deep dorsal vein of the penis communicates with the internal pudendal veins, but ends mainly in the pudendal plexus.

4. The **obturator vein** begins in the upper portion of the adductor region of the thigh and enters the pelvis through the upper part of the obturator foramen. It runs backwards and upwards on the lateral wall of the pelvis below the obturator artery, passes between the ureter and the hypogastric artery, and ends in the hypogastric vein. Sometimes it is replaced by an enlarged pubic vein (p. 699) which joins the external iliac vein.

5. The **lateral sacral veins** accompany the lateral sacral arteries and end in the hypogastric vein.

6. The **middle hæmorrhoidal vein** varies in size; it begins in the hæmorrhoidal plexus and receives tributaries from the bladder, prostate, and seminal vesicle; it runs lateralwards on the pelvic surface of the Levator ani and ends in the hypogastric vein.

The **hæmorrhoidal plexus** surrounds the rectum, and communicates in front with the vesical plexus in the male, and the uterovaginal plexus in the female. It consists of two parts, an *internal* in the submucosa, and an *external* outside the muscular coat of the rectum. The internal plexus presents a series of dilated pouches which are arranged in a circle around the tube, immediately above the anal orifice, and are connected by transverse branches; it drains mainly into the superior hæmorrhoidal vein.

The lower part of the external plexus is drained by the inferior hæmorrhoidal veins into the internal pudendal vein; the middle part by the middle hæmorrhoidal vein into the hypogastric vein; and the upper part by the superior hæmorrhoidal vein which forms the commencement of the inferior mesenteric vein, a tributary of the portal vein. A free communication between the portal and systemic venous systems is established through the hæmorrhoidal plexus.

The **pudendal plexus** lies behind the arcuate pubic ligament and the lower part of the symphysis pubis, and in front of the bladder and prostate. Its chief tributary is the deep dorsal vein of the penis, but it also receives branches from the front of the bladder and prostate. It communicates with the vesical plexus and with the internal pudendal vein, and drains into the vesical and hypogastric veins. The *prostatic veins* form a well-marked *prostatic plexus* which lies partly in the fascial sheath of the prostate and partly between the sheath and the prostatic capsule. It communicates with the pudendal and vesical plexuses.

The **vesical plexus** envelops the lower part of the bladder and the base of the prostate and communicates with the pudendal and prostatic plexuses. It is drained, by means of several vesical veins, into the hypogastric veins.

Applied Anatomy.—The veins of the hæmorrhoidal plexus are apt to become dilated and varicose, and form piles. This is due to several anatomical reasons: the vessels are contained in very loose connective tissue, so that they get less support from surrounding structures than most other veins, and are less capable of resisting increased blood-pressure; the condition is favoured by gravitation, being influenced by the erect posture,

either sitting or standing, and by the fact that the superior hæmorrhoidal and portal veins have no valves; the veins pass through muscular tissue and are liable to be compressed by its contraction, especially during the act of defæcation; they are affected by every form of portal obstruction.

The prostatic plexus of veins is apt to become congested in inflammatory conditions in the neighbourhood, such as acute gonorrhœal prostatitis. It is owing to the free communication which exists between this and the middle hæmorrhoidal plexus that great relief can be given by free saline purgation.

Hæmorrhage may be very free from the prostatic plexus after operations on that gland, but can usually be checked by hot fluid irrigation. Septic thrombosis sometimes occurs after operations, and infected emboli may find their way into the general circulation.

The dorsal veins of the penis are two in number, a superficial and a deep. The *superficial dorsal vein* drains the prepuce and skin of the penis, and, running backwards in the subcutaneous tissue, inclines to the right or left, and opens into the corresponding superficial external pudendal vein, a tributary of the great saphenous vein. The *deep dorsal vein* lies within the fibrous envelope of the penis; it receives blood from the glans penis and corpora cavernosa penis, and courses backwards in the middle line between the dorsal arteries; near the root of the penis it passes between the two parts of the suspensory ligament and then through an aperture between the arcuate pubic ligament and the transverse ligament of the pelvis, and divides into two branches, which enter the pudendal plexus. It also communicates below the symphysis pubis with the internal pudendal vein.

The uterine plexuses lie along the sides and superior angles of the uterus between the two layers of the broad ligament, and communicate with the ovarian and vaginal plexuses. They are drained by a pair of uterine veins on either side; these arise from the lower parts of the plexuses, opposite the external orifice of the uterus, and open into the corresponding hypogastric vein.

The vaginal plexuses are placed at the sides of the vagina; they communicate with the uterine, vesical, and hæmorrhoidal plexuses, and are drained by the vaginal veins, one on either side, into the hypogastric veins.

The common iliac veins are formed by the union of the external iliac and hypogastric veins, in front of the sacro-iliac articulation; passing obliquely upwards they end on the right side of the fifth lumbar vertebra by uniting with each other at an acute angle to form the inferior vena cava. The *right common iliac vein*, shorter than the left, is nearly vertical in its direction, and ascends behind, and then lateral to its artery. The *left common iliac vein*, longer and more oblique than the right, is at first situated on the medial side of its artery, and then behind the right common iliac artery. Each common iliac vein receives the iliolumbar, and sometimes the lateral sacral veins; the left vein receives the middle sacral vein. There are no valves in these veins.

The middle sacral veins accompany the corresponding artery along the front of the sacrum, and join to form a single vein, which usually ends in the left common iliac vein, but sometimes in the angle of junction of the two common iliac veins.

Peculiarities.—The left common iliac vein, instead of joining with the right in its usual position, occasionally ascends on the left side of the aorta as high as the kidney, where, after receiving the left renal vein, it crosses the aorta, and joins the right vein to form the vena cava. In these cases, the two common iliac veins are connected by a small communicating branch at the spot where they are usually united.

The inferior vena cava (fig. 675) conveys the blood from the parts below the Diaphragm to the heart. It is formed by the junction of the two common iliac veins, on the right side of the fifth lumbar vertebra. It ascends in front of the vertebral column, on the right side of the aorta, and, having reached the liver, is contained in a deep groove on its posterior surface. It then perforates the Diaphragm between the median and right portions of its central tendon; it subsequently inclines forwards and medialwards for about 2.5 cm., and, piercing the fibrous pericardium, passes behind the serous pericardium to open into the lower and posterior part of the right atrium. In front of its atrial orifice is a semilunar valve, termed the *valve of the inferior vena cava* (Eustachian valve); this valve is rudimentary in the adult, but is of large size and exercises an important function in the fœtus (p. 566).

Relations.—The *abdominal portion* of the inferior vena cava is in relation in front, from below upwards, with the right common iliac artery, the lower part of the mesentery and its vessels, the right testicular artery, the inferior part of the duodenum, the head of the pancreas, the epiploic foramen, the common bile-duct, the portal vein, the hepatic artery, and the posterior surface of the liver; the last partly overlaps and occasionally completely surrounds it; *behind*, with the vertebral column, the right Psoas major, the right crus of the Diaphragm, the right inferior phrenic, suprarenal, renal and lumbar arteries, right sympathetic trunk and right coeliac ganglion, and the medial part of the right suprarenal gland; on the *right side*, with the right kidney and ureter; on the *left side*, with the aorta, right crus of the Diaphragm, and the caudate lobe of the liver.

The *thoracic portion* is only about 2.5 cm. in length, and is situated partly inside and partly outside the pericardial sac. The *extrapericardial part* is separated from the right pleura and lung by a fibrous band, named the *right phrenicopericardiac ligament*. This ligament, often feebly marked, is attached below to the margin of the vena-caval opening in the Diaphragm and above to the pericardium in front of the root of the right lung. The *intrapericardiac part* is very short and is covered anterolaterally by the serous layer of the pericardium.

Peculiarities.—This vessel is sometimes placed on the left side of the aorta, as high as the left renal vein, and, after receiving this vein, crosses over to its usual position on the right side; or it may be placed altogether on the left side of the aorta, and in such a case the abdominal and the thoracic viscera, together with the great vessels, are all transposed. Occasionally it joins the azygos vein, which is then of large size. In such cases, the superior vena cava receives the whole of the blood from the body, except that from the hepatic veins, which passes directly into the right atrium.

Applied Anatomy.—Thrombosis of the inferior vena cava is due to much the same causes as that of the superior (p. 693). It usually causes oedema of the legs and back, without ascites; if the renal veins are involved, blood and albumin will often appear in the urine. An extensive collateral venous circulation is soon established by enlargement either of the superficial or of the deep veins, or of both. In the first case the epigastric, the iliac circumflex, the lateral thoracic, the internal mammary, the intercostals, the external pudendal, and the lumbovertebral anastomotic veins of Braune effect the communication with the superior cava; in the second, the deep anastomosis is made by the azygos and hemiazygos and the lumbar veins.*

Tributaries.—In addition to the two common iliac veins the inferior vena cava receives the following veins.

Lumbar.	Renal.	Right inferior phrenic.
Right testicular or ovarian.	Right suprarenal.	Hepatic.

The **lumbar veins**, four in number on either side, collect the blood by dorsal tributaries from the muscles and skin of the loins, and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the vertebral column, they receive veins from the vertebral plexuses, and then pass forwards on the sides of the bodies of the vertebræ, beneath the Psoas major, and end in the posterior part of the inferior vena cava. The left lumbar veins are longer than the right, and run behind the aorta. The lumbar veins are connected together by a longitudinal vein which passes in front of the transverse processes of the lumbar vertebræ, and is called the *ascending lumbar vein*; it forms the most frequent origin of the corresponding azygos or hemiazygos vein, and serves to connect the common iliac, ilio-lumbar, and azygos or hemiazygos veins of its own side of the body.

The **testicular veins** (spermatic veins) emerge from the back of the testis, and receive tributaries from the epididymis; they unite and form a convoluted plexus, called the *pampiniform plexus* which constitutes the greater mass of the spermatic cord and ascends along the cord, in front of the ductus deferens. Below the subcutaneous inguinal ring the veins of the plexus unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the abdominal inguinal ring, coalesce to form two veins, which run upwards in front of the Psoas major and the ureter, behind the peritoneum, lying one on either side of the testicular artery. These two veins

* G. Blumer, in Osler and McCrae's *System of Medicine*, London, 1908, vol. iv.

join to form a single vein, which opens on the right side into the inferior vena cava at an acute angle; on the left side into the left renal vein at a right angle. The testicular veins are provided with valves.* The left vein passes behind the iliac part of the descending colon and the lower margin of the pancreas, the right behind the terminal part of the ilium and the inferior part of the duodenum.

Applied Anatomy.—The testicular veins are very frequently varicose, constituting the condition known as *varicocele*. Though it is quite possible that the originating cause of this affection may be a congenital weakness of the walls of the veins of the pampiniform plexus, it must be admitted that there are anatomical reasons why these veins should become varicose: viz. the imperfect support afforded to them by the loose tissue of the scrotum; their great length; their vertical course; their dependent position; their plexiform arrangement in the scrotum, with their termination in one small vein in the abdomen; their few and imperfect valves; and the fact that they may be subjected to pressure in their passage through the abdominal wall. Varicocele almost invariably occurs on the left side, and this has been accounted for by the facts that the left testicular vein joins the left renal at a right angle; that it is overlaid by the iliac part of the descending colon, and that when this portion of the gut is full of fecal matter, in cases of constipation, its weight impedes the return of the venous blood; and finally that the left testicular veins are somewhat longer than the right.

The operation for the removal of a varicocele consists in making a small incision just over the subcutaneous inguinal ring; the cord is lifted out and the spermatic fascia incised; the plexus of veins is then isolated from the ductus deferens and ligatured above and below, as high and as low as possible, and the intermediate portion cut away: the divided ends are fixed together with a suture, and the skin wound closed. The venous return is subsequently carried out by the small veins of the ductus deferens, of the Cremaster and those connecting with the scrotal tissues. In removing a varicocele the testicular artery is generally removed at the same time.

The ovarian veins in the female correspond with the testicular veins in the male; each forms a plexus between the layers of the broad ligament near the ovary and uterine tube, and communicates with the uterine plexus. Two veins issue from this plexus and ascend in front of the external iliac artery, one lying on either side of the ovarian. Their further course and their mode of termination are the same as those of the testicular veins. Valves are occasionally found in the ovarian veins. Like the uterine veins, they become much enlarged during pregnancy.

The renal veins are of large size, and are placed in front of the renal arteries. The left is thrice the length of the right (7.5 cm. to 2.5 cm.), and passes in front of the aorta, just below the origin of the superior mesenteric artery. It receives the left testicular (or ovarian) and one of the left inferior phrenic veins, and, generally, the left suprarenal vein. It opens into the inferior vena cava at a slightly higher level than the right.

The suprarenal veins are two in number: the right ends in the inferior vena cava; the left usually in the left renal.

The inferior phrenic veins follow the course of the inferior phrenic arteries on the Diaphragm; the right ends in the inferior vena cava; the left is often represented by two branches, one of which ends in the left renal or suprarenal vein, while the other passes in front of the oesophageal hiatus in the Diaphragm and opens into the inferior vena cava.

The hepatic veins drain the liver, and commence in the *intra-lobular veins* which receive the blood from the sinusoids of the liver lobules. The intra-lobular veins open into the *sublobular veins*, and these in turn unite to form the hepatic veins which open into that portion of the inferior vena cava which lies in the groove on the posterior surface of the liver. The hepatic veins are arranged in two groups, upper and lower. The *upper group* usually consists of three large veins; those of the *lower group* vary in number, are of small size and come from the right and caudate lobes. The hepatic veins are in direct contact with the hepatic tissue and are destitute of valves.

* Rivington has pointed out that valves are usually found at the orifices of both the right and left testicular veins. When, however, valves are not found at the opening of the left vein into the left renal vein, they are generally present in the left renal vein within 6 mm. from the orifice of the testicular vein.—*Journal of Anatomy and Physiology*, vol. vii. p. 163.

PORTAL SYSTEM OF VEINS (fig. 682)

The portal system includes all the veins which drain the blood from the abdominal part of the digestive tube (with the exception of the lower part of the rectum) and from the spleen, pancreas, and gall bladder. From these viscera the blood is conveyed to the liver by the *portal vein*. In the liver this vein ramifies like an artery and ends in capillary-like vessels termed sinusoids, from which the blood is conveyed to the inferior vena cava by the hepatic

FIG. 682.—Portal vein and its tributaries.



veins. The blood of the portal system therefore passes through two sets of minute vessels, viz. (a) the capillaries of the digestive tube, spleen, pancreas, and gall bladder; and (b) the sinusoids of the liver. In the adult the portal vein and its tributaries are destitute of valves; in the foetus and for a short time after birth valves can be demonstrated in the tributaries of the portal vein; ~~as a~~ rule they atrophy and disappear, but sometimes persist in a degenerate form.

The portal vein is about 8 cm. long, and is formed at the level of the second lumbar vertebra by the junction of the superior mesenteric and hepatic

(splenic) veins, the union of these veins taking place in front of the inferior vena cava and behind the neck of the pancreas. It passes upwards behind the superior part of the duodenum, and then ascends in the right border of the lesser omentum to the right extremity of the porta hepatis (transverse fissure of the liver), where it divides into a right and a left branch, which accompany the corresponding branches of the hepatic artery into the substance of the liver. In the lesser omentum it is placed behind and between the common bile duct and the hepatic artery, the former lying to the right of the latter; it is surrounded by the hepatic plexus of nerves, and is accompanied by numerous lymphatic vessels and some lymph-glands. The *right branch* of the portal vein enters the right lobe of the liver, but before doing so generally receives the cystic vein. The *left branch*, longer but of smaller calibre than the right, crosses the left sagittal fossa (longitudinal fissure), gives branches to the caudate lobe, and then enters the left lobe of the liver. As it crosses the left sagittal fossa it is joined in front by a fibrous cord, the *ligamentum teres* or *obliterated umbilical vein*, and is united to the inferior vena cava by a second fibrous cord, the *ligamentum venosum* or *obliterated ductus venosus*.

The tributaries of the porta vein are :

- | | |
|-------------------------|-------------------|
| 1. Lienal (Splenic). | 4. Right gastric. |
| 2. Superior mesenteric. | 5. Cystic. |
| 3. Coronary. | 6. Parumbilical. |

1. The **lienal or splenic vein** is of large size, but is not tortuous like the artery; it commences by five or six branches which return the blood from the spleen. These unite to form a single vessel, which passes from left to right, grooving the upper part of the posterior surface of the pancreas, below the lienal artery, and ends behind the neck of the pancreas by uniting at a right angle with the superior mesenteric vein, to form the portal vein.

Tributaries.—It receives the short gastric veins, the left gastro-epiploic vein, the pancreatic veins, and the inferior mesenteric vein.

(a) The **short gastric veins**, four or five in number, drain the fundus and left part of the greater curvature of the stomach, and pass between the two layers of the gastrolial ligament to end in the lienal vein or in one of its large tributaries.

(b) The **left gastro-epiploic vein** receives branches from the surfaces of the stomach and from the greater omentum; it runs from right to left along the greater curvature of the stomach and ends in the commencement of the lienal vein.

(c) The **pancreatic veins** are several small vessels which drain the body and tail of the pancreas.

(d) The **inferior mesenteric vein** returns blood from the rectum, and from the sigmoid and descending parts of the colon. It begins in the rectum as the *superior hæmorrhoidal vein*, which has its origin in the hæmorrhoidal plexus (p. 700), and through this plexus communicates with the middle and inferior hæmorrhoidal veins. The superior hæmorrhoidal vein leaves the lesser pelvis, crosses the left common iliac vessels with the superior hæmorrhoidal artery, and is continued upwards as the inferior mesenteric vein. This vein lies to the left of its artery and ascends behind the peritoneum and in front of the left Psoas major; it then passes behind the body of the pancreas and opens into the lienal vein; sometimes it ends in the angle of union of the lienal and superior mesenteric veins.

Tributaries.—The inferior mesenteric vein receives the sigmoid veins from the sigmoid colon, and the left colic vein from the descending colon and left colic flexure.

2. The **superior mesenteric vein** returns the blood from the small intestine, from the cæcum, and from the ascending and transverse portions of the colon. It begins in the right iliac fossa by the union of the veins which drain the terminal part of the ileum, the cæcum and vermiform process. It ascends between the two layers of the mesentery on the right side of the superior mesenteric artery, and in its upward course passes in front of the right ureter, the inferior vena cava, the inferior part of the duodenum, and the processus uncinatus of the head of the pancreas. Behind the neck of the pancreas it unites with the lienal vein to form the portal vein.

Tributaries.—The superior mesenteric vein receives the veins which correspond with the branches of the superior mesenteric artery, viz. the jejunal, ileal, ileocolic,

right colic, and middle colic veins; it is also joined by the right gastro-epiploic and the pancreaticoduodenal veins.

The **right gastro-epiploic vein** receives branches from the greater omentum and from the lower part of the stomach; it runs from left to right along the greater curvature of the stomach, between the two layers of the greater omentum.

The **pancreaticoduodenal veins** accompany their corresponding arteries; the lower one frequently joins the right gastro-epiploic vein.

3. The **coronary vein** derives tributaries from both surfaces of the stomach: it runs from right to left along the lesser curvature of the stomach between the two layers of the lesser omentum, to the oesophageal opening of the stomach, where it receives some oesophageal veins. It then turns backwards and passes from left to right behind the omental bursa, and ends in the portal vein.

4. The **right gastric vein** (pyloric vein), of small size, runs from left to right along the pyloric portion of the lesser curvature of the stomach between the two layers of the lesser omentum, and ends in the portal vein.

5. The **cystic vein** drains the blood from the gall-bladder; it accompanies the cystic duct, and usually ends in the right branch of the portal vein.

6. **Parumbilical veins.**—In the course of the ligamentum teres of the liver and of the middle umbilical ligament, small veins (parumbilical) are found, which establish an anastomosis between the veins of the anterior abdominal wall and the portal, hypogastric, and iliac veins. The best marked of these small veins is one which begins at the umbilicus and runs backwards and upwards in, or on the surface of, the ligamentum teres between the layers of the falciform ligament, to end in the left portal vein.

Applied Anatomy.—Obstruction to the portal vein may produce ascites, and this may arise from many causes, e.g. (1) the pressure of a tumour on the portal vein, such as cancer or hydatid cyst in the liver, enlarged lymph-glands in the lesser omentum, or cancer of the head of the pancreas; (2) from cirrhosis of the liver, when the radicles of the portal vein are pressed upon by the contracting fibrous tissue in the portal canals; (3) from valvular disease of the heart, and back pressure on the hepatic veins, and so on the whole of the circulation through the liver. In this condition the prognosis as regards life and freedom from ascites may be much improved by the establishment of a good collateral venous circulation to relieve the portal obstruction in the liver. This is effected by communications between (a) the gastric veins, and the oesophageal veins which often project as a varicose bunch into the stomach, emptying themselves into the hemiazygos vein; (b) the veins of the colon and duodenum, and the left renal vein; (c) the accessory portal system of Sappey, branches of which pass in the round and falciform ligaments (particularly the latter) to unite with the epigastric and internal mammary veins, and through the diaphragmatic veins with the azygos; a single large vein, shown to be a parumbilical vein, may pass from the hilum of the liver by the round ligament to the umbilicus, producing there a bunch of prominent varicose veins known as the *caput Medusæ*; (d) the veins of Retzius, which connect the intestinal veins with the inferior vena cava and its retroperitoneal branches; (e) the inferior mesenteric veins, and the hæmorrhoidal veins that open into the hypogastriacs; (f) very rarely the ductus venosus remains patent, affording a direct connexion between the portal vein and the inferior vena cava.

An operation for the relief of portal obstruction on these lines has been advocated by Rutherford Morison and by Talma. It consists in roughening the opposed surfaces of the liver and Diaphragm and stitching them together, so as to secure vascular inflammatory adhesions between the two. The greater omentum may with advantage be interposed between them, so as to increase the amount of the adhesions.

Thrombosis of the portal vein is a very serious event, and is oftenest due to pathological processes causing compression of the vessel or injury to its wall, such as tumours or inflammation about the pylorus or head of the pancreas, or to gall-stones, or cirrhosis of the liver.

Thrombosis of the mesenteric veins produces very acute symptoms, similar to those of embolism of the mesenteric arteries (see p. 639).

Infective emboli lodging in the portal venules give rise to a condition known as *septic* or *suppurative pylephlebitis* or, more shortly, *portal pyæmia*. They occur most often in one of the ileocolic radicles, and are due to appendicitis, but the infection may arise from anywhere in the portal system (e.g. the superior hæmorrhoidal radicles). Fragments of the infected clot break off from the original thrombus and lodge in the smaller veins of the liver, causing the development of multiple abscesses in its substance, and a rapidly fatal result. A similar path of infection is taken by the *entamoeba histolytica* of dysentery, when it passes into the liver and produces *tropical abscess*.

THE LYMPHATIC SYSTEM

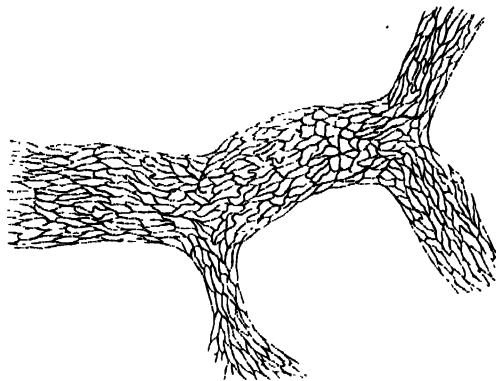
The lymphatic system includes the lymphatic vessels and lymph-glands. The lymphatic vessels of the small intestine receive the special designation of *lacteals* or *chyliferous vessels*; they differ in no respect from the lymphatic vessels generally, excepting that during the process of absorption of a fatty meal they contain a milk-white fluid, the *chyle*. In most of the tissues of the body there are also minute spaces and channels which contain lymph; the cells of connective tissue, for example, are bathed in this fluid. As fresh lymph is formed by transudation from the blood-capillaries, that lying in the tissue-spaces is moved on into the lymphatic vessels, which probably commence in every case, as those in the intestinal villi are known to do, by blind extremities.

The **lymphatic vessels** are exceedingly delicate, and their coats are so transparent that the fluid they contain is readily seen through them. They are constricted at intervals and so present a knotted or beaded appearance; these constrictions correspond to the situations of valves in the interior of the vessels. Lymphatic vessels have been found in nearly every texture and organ of the body which contains blood-vessels. Non-vascular structures such as cartilage, nails, cuticle, and hair have none, but with these exceptions it is probable that all parts are permeated by these vessels.

Structure of lymphatic vessels.—The larger lymphatic vessels are each composed of three coats. The *internal* coat is thin, transparent, slightly elastic, and consists

of a layer of elongated endothelial cells supported on an elastic membrane; the cells have wavy margins by which the contiguous cells are dovetailed into one another. The *middle* coat is composed of smooth muscular, and fine elastic, fibres, disposed in a transverse direction. The *external* coat consists of connective tissue, intermixed with smooth muscular fibres longitudinally or obliquely disposed; it forms a protective covering to the other coats, and serves to connect the vessel with the neighbouring structures. In the smaller vessels there are no muscular or elastic fibres, and the wall consists only of a connective tissue coat lined by endothelium (fig. 683). The thoracic duct has a more complex structure than the other lymphatic vessels; it presents a distinct subendothelial layer, similar to that found in the arteries; in the middle coat there is, in addition to the muscular and elastic fibres, a layer of connective tissue with its fibres arranged longitudinally. The larger lymphatic vessels are supplied by nutrient vessels, which are distributed to their outer and middle coats; and here also have been traced many non-medullated nerves in the form of a fine plexus of fibrils.

FIG. 683.—Small lymphatic vessel, from diaphragm of a rabbit. Silvered. $\times 65$.



(fig. 683). The thoracic duct has a more complex structure than the other lymphatic vessels; it presents a distinct subendothelial layer, similar to that found in the arteries; in the middle coat there is, in addition to the muscular and elastic fibres, a layer of connective tissue with its fibres arranged longitudinally. The larger lymphatic vessels are supplied by nutrient vessels, which are distributed to their outer and middle coats; and here also have been traced many non-medullated nerves in the form of a fine plexus of fibrils.

In the lymphatic vessels the valves are placed at much shorter intervals than in the veins. They are most numerous near the lymph-glands, and are found more frequently in the lymphatic vessels of the neck and upper extremity than in those of the lower extremity; they are wanting in the vessels composing the plexiform network in which the lymphatic vessels usually originate on the surface of the body. The valves are formed of thin layers of fibrous tissue covered on both surfaces by endothelium which presents the same arrangement as on the valves of veins (p. 550). They are semilunar in form, and are attached by their convex edges to the wall of the vessel, the concave edges being free and directed along the course of the lymph-current. Usually two valves, of equal size, are found opposite one another; but occasionally exceptions occur, especially at or near the anastomoses of lymphatic vessels; thus, one valve may be of small size and the other increased in proportion. The wall of a lymphatic vessel immediately above the attachment of each segment

of a valve is expanded into a pouch or sinus which gives the vessel, when distended, the knotted or beaded appearance already referred to.

The **lymph-glands** are small oval or bean shaped bodies, situated in the course of lymphatic and lacteal vessels so that the lymph and chyle pass through them on their way to the blood. Each generally presents on one side a slight depression, the *hilum*, through which the blood-vessels enter and leave the gland. The efferent lymphatic vessel also emerges from the gland at this spot, while the afferent vessels enter it at different parts of the periphery. On section (fig. 684), a lymph-gland displays two different structures: an external, of lighter colour--the *cortical*; and an internal, darker--the *medullary*. The cortical structure does not form a complete investment, but is deficient at the hilum, where the medullary portion reaches the surface of the gland; so that the efferent lymphatic vessel is derived directly from the medullary structure, while the afferent vessels empty themselves into the cortical substance.

Structure of lymph-glands (figs. 684, 685).—A lymph-gland consists of (1) a fibrous envelope, or *capsule*, from which a framework of processes (*trabeculae*) proceeds inwards, imperfectly dividing the gland into open spaces freely communicating with each other; (2) a quantity of lymphoid tissue occupying these spaces without

FIG. 684.—Section of a lymph-gland of a cat. Stained with hæmatoxylin and cosin. $\times 15$.



completely filling them; (3) a free supply of blood-vessels, which are supported in the trabeculae; and (4) the *afferent* and *efferent lymphatic vessels* communicating through the lymph-paths in the substance of the gland. The nerves passing into the hilum are few in number and are chiefly distributed to the blood-vessels supplying the gland.

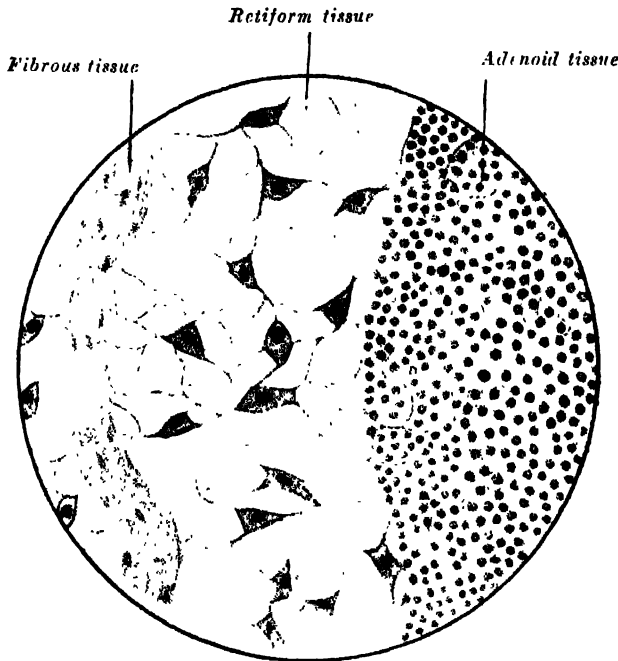
In man the *capsule* and *trabeculae* are composed of connective tissue with some plain muscle-fibres, but in many of the lower animals they consist almost entirely of involuntary muscle. The trabeculae pass inwards towards the centre of the gland for a certain distance—that is to say, for about one-third or one-fourth of the space between the circumference and the centre of the gland. In some animals they are sufficiently well marked to divide the peripheral or cortical portion of the gland into a number of compartments (so-called follicles), but in man this arrangement is not obvious. The larger trabeculae springing from the capsule break up into finer bands, and these interlace to form a meshwork in the central or medullary portion of the gland. The gland-pulp or lymphoid tissue is contained in the spaces formed by the interlacing trabeculae; it does not, however, completely fill the spaces, but leaves, between its outer margin and the enclosing trabeculae, a channel or space, termed the *lymph-path* or *lymph-sinus*; the lymph-path is bridged by a network of retiform tissue (fig. 685).

On account of the peculiar arrangement of the framework, the gland-pulp in the cortical portion is disposed in the form of nodules, and in the medullary part in the form of rounded cords. It consists of ordinary lymphoid tissue (fig. 685), being made up of a delicate network of retiform tissue packed with lymphocytes. The network of the gland-pulp is continuous with that in the lymph-paths, but marked off from it by a closer reticulation; moreover, the fibres of the retiform

tissue of the lymph-paths are continuous with those of the trabeculae. The gland-pulp is traversed by a dense plexus of capillary blood-vessels. The nodules or follicles in the cortical portion of the gland frequently show areas where karyokinetic figures indicate a division of the lymph-corpuscles. These areas are termed *germ-centres*. The actively dividing cells have more abundant protoplasm than those which are not undergoing division, and consequently in stained sections the germ-centres appear clearer than the surrounding gland-pulp.

The *afferent vessels*, as stated above, enter at different parts of the periphery of the gland, and after branching and forming a dense plexus in the substance of the capsule, open into the lymph-sinuses of the cortical part. In doing this they lose all their coats except their endothelial lining, which is continuous with a layer of similar cells lining the lymph-paths. The *efferent vessel* commences from the lymph-sinuses of the medullary portion. The stream of lymph carried to the gland

FIG. 685.--Retiform and adenoid tissue, from a lymph-gland. $\times 255$.



by the afferent vessels thus passes through the plexus in the capsule to the lymph-paths of the cortical portion, where it is exposed to the action of the gland-pulp; flowing through these it enters the paths or sinuses of the medullary portion, and finally emerges from the hilum by means of the efferent vessel. The stream of lymph in its passage through the lymph-sinuses is much retarded by the presence of the reticulum, hence morphological elements, either normal or morbid, are easily arrested and deposited in the sinuses. Many lymph-corpuscles pass with the efferent lymph-stream to join the general blood-stream. The arteries of the gland enter at the hilum, and go to the gland-pulp, to break up into a capillary plexus, either directly or after running in the trabeculae for a certain distance. The veins emerge from the gland at the hilum.

The lymphatic vessels are arranged into a superficial and a deep set. On the surface of the body the *superficial* lymphatic vessels are placed immediately beneath the skin and accompany the superficial veins; they join the deep lymphatic vessels in certain situations. In the interior of the body they lie in the submucous areolar tissue throughout the whole length of the digestive, respiratory and genito-urinary tracts; and in the subserous tissue of the thoracic and abdominal walls. Networks of minute lymphatic vessels are found interspersed among the elements and blood-vessels of the several tissues; the vessels composing the network as well as the meshes between them, are

much larger than those of the capillary plexus. From these networks small vessels emerge, which pass, either to a neighbouring gland, or to join some larger lymphatic trunk. The deep lymphatic vessels, fewer in number, but larger than the superficial, accompany the deep blood-vessels. Their mode of origin is probably similar to that of the superficial vessels.

The lymphatic vessels of any part or organ exceed the veins in number, but in size they are much smaller. Their anastomoses also, especially those of the large trunks, are more frequent, and are effected by vessels equal in diameter to those which they connect.

Applied Anatomy.—The lymphatic vessels and lymph-glands draining any infected area of the body are very liable to become inflamed, resulting in acute or chronic lymphangitis and lymphadenitis. In acute cases the paths of the superficial lymphatic vessels are often marked out on the skin by pain, redness, heat, and swelling, while the lymph-glands swell and may suppurate. Chronic inflammation leads to growth and fibrosis of the lymphatic vessels and the connective tissue round them; obstruction to the passage of the lymph results, as the fibrous tissue contracts and causes stenosis or obliteration of the lymphatic channels, and hard oedema of the involved skin and subcutaneous tissues follows (pachydermia lymphangiectatica). Chronic lymphangitis, together with the blocking of numerous lymphatic vessels by the escaped ova of the minute parasitic worm *Microfilaria nocturna*, is the cause of elephantiasis, a condition common in the tropics and subtropics, and characterised by enormous enlargement and thickening of the skin of some part of the body, most frequently of the leg. Tuberculous and syphilitic enlargements of the lymphatic vessels and lymph-glands are both very commonly met with. Primary tumours of the lymphatic vessels are lymphangioma and endothelioma; the so-called 'congenital cystic hygroma' of the neck, arm, trunk, or thigh, is a cystic lymphangioma. Primary tumours of the lymph-glands may be innocent (lymphadenoma, myxoma, chondroma) or malignant (lymphosarcoma); cancer is never met with as a primary affection, but is extremely common secondarily to cancer of some other part of the body.

The appearance of secondary malignant deposits or of secondary infection in parts of the body that seem not to be directly associated by any lymphatic connexion with the seat of the primary growth or infection has often been observed, and explained as due to 'retrograde transport' of cancer-cells or bacteria by a reversed flow of lymph. Welninsky,* however, believes that the explanation is to be found in the fact that when the infected lymph-glands have grown to a certain size they no longer permit the normal flow of lymph through them, and that under these circumstances very delicate lymphatic connexions, whose existence normally remains unsuspected, develop to a surprising extent between groups of lymph-glands that at first sight appear to be unconnected with one another.

THORACIC DUCT

The thoracic duct (fig. 683) conveys the chyle and the greater part of the lymph into the blood. It is the common trunk of all the lymphatic vessels of the body, excepting those of the right side of the head, neck, and thoracic wall, the right upper extremity, right lung, right side of the heart, and part of the convex surface of the liver. In the adult it varies in length from 38 cm. to 45 cm., and extends from the second lumbar vertebra to the root of the neck. It begins in a triangular dilatation, the *cisterna chyli*, which is situated on the front of the bodies of the first and second lumbar vertebrae, to the right side of and behind the aorta, by the side of the right crus of the Diaphragm. It enters the thorax through the aortic hiatus of the Diaphragm, and ascends through the posterior mediastinal cavity with the aorta on its left and the azygos vein on its right side. Behind it in this region are the vertebral column, the right intercostal arteries, and the hemiazygos and accessory hemiazygos veins. In front of it are the Diaphragm, œsophagus, and pericardium, the last being separated from it by a recess of the right pleural cavity. Opposite the fifth thoracic vertebra, it inclines towards the left side, enters the superior mediastinal cavity, and ascends behind the aortic arch and the thoracic part of the left subclavian artery and between the left side of the œsophagus and the left pleura, to the upper orifice of the thorax. Passing into the neck it forms an arch which rises about 3 cm. or 4 cm. above the clavicle and turns forwards anterior to the first part of the subclavian artery, the vertebral artery and vein, and the thyrocervical trunk or its branches. It also passes in front of the phrenic nerve and the medial border of the Scalenus anterior, but is

* *Berliner Klin. Woch.*, 1905, No. 24, p. 743.

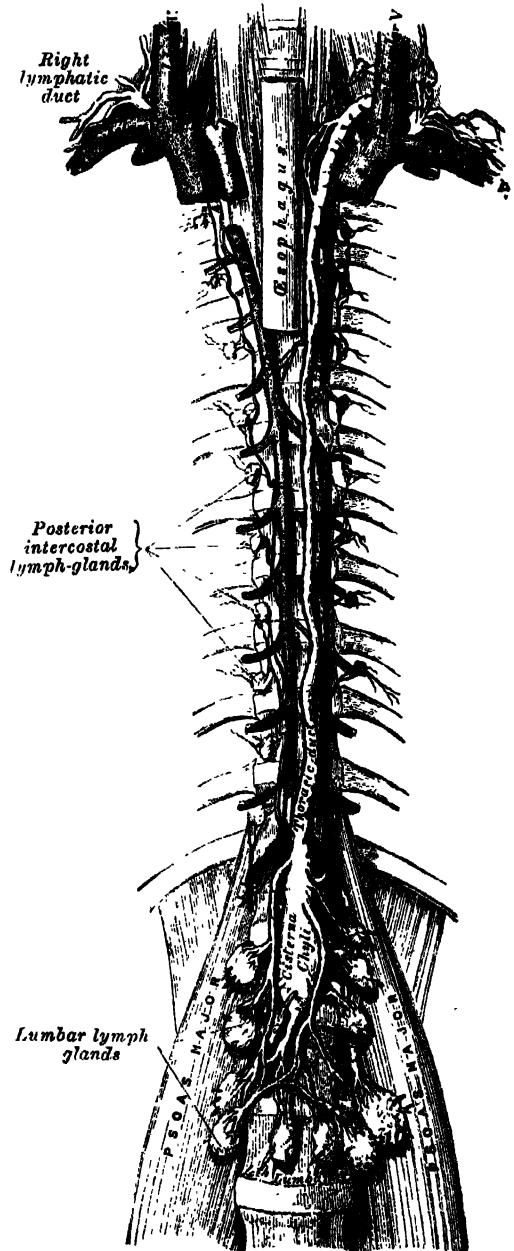
separated from these two structures by the prevertebral fascia. In front of it are the left common carotid artery, vagus nerve, and internal jugular vein; it ends by opening into the angle of junction of the left subclavian vein with the left internal jugular vein. The thoracic duct, at its commencement, is about equal in diameter to a goose-quill, but it diminishes considerably in calibre in the middle of the thorax, and is again slightly dilated just before its termination. It is generally flexuous, and constricted at intervals so as to present a varicose appearance. Not infrequently it divides in the middle of its course into two vessels of unequal size which soon reunite, or into several branches which form a plexiform interlacement. It occasionally divides at its upper part into two branches, right and left: the left ending in the usual manner, while the right opens into the right subclavian vein, in connexion with the right lymphatic duct.

The thoracic duct has several valves; at its termination it is provided with a pair, the free borders of which are turned towards the vein, so as to prevent the passage of venous blood into the duct.

The cisterna chyli (fig. 687) receives the two lumbar lymphatic trunks, right and left, and the intestinal lymphatic trunk. The *lumbar trunks* are formed by the union of the efferent vessels from the lateral aortic lymph-glands; they receive the lymph from the lower limbs, from the walls and viscera of the pelvis, from the kidneys and suprarenal glands, and the deep lymphatics of the greater part of the abdominal wall. The *intestinal trunk* receives the lymph from the stomach, intestine, pancreas and spleen, and from the lower and front part of the liver.

Tributaries.—Opening into the commencement of the thoracic duct, on either side, is a descending trunk from the posterior intercostal lymph-glands of the lower six or seven intercostal spaces. In the thorax the duct is joined on either side by a trunk which drains the upper lumbar lymph-glands and pierces the crus of the Diaphragm. It also receives the offerents from the posterior mediastinal lymph-glands and from the posterior intercostal lymph-glands of the upper six left spaces. In the neck it is joined by the *left jugular*

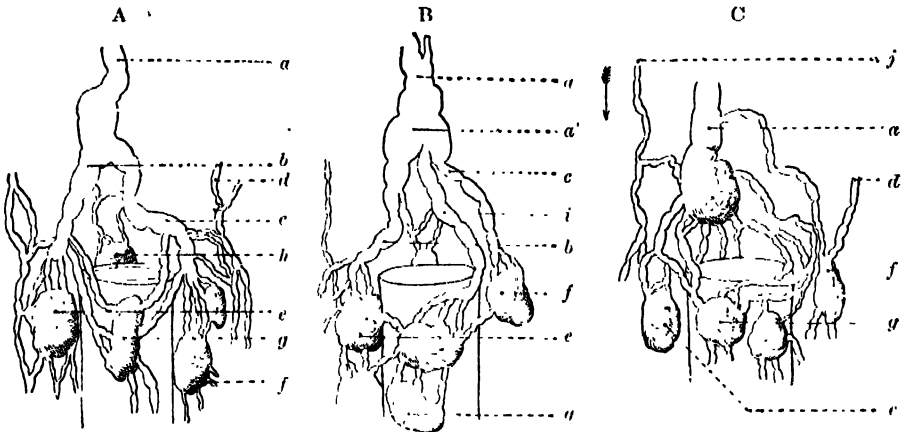
FIG. 686.—The thoracic and right lymphatic ducts.



trunk from the left side of the head and neck, and *left subclavian trunk* from the left superior extremity; sometimes it is joined by the *left bronchomediastinal trunk*, but this trunk usually opens independently into the junction of the left subclavian and internal jugular veins.

The **right lymphatic duct** (fig. 686), about 1.25 cm. in length, courses along the medial border of the *Scalenus anterior* at the root of the neck, and

FIG. 687.—Modes of origin of thoracic duct. (Poirier and Charpy.)

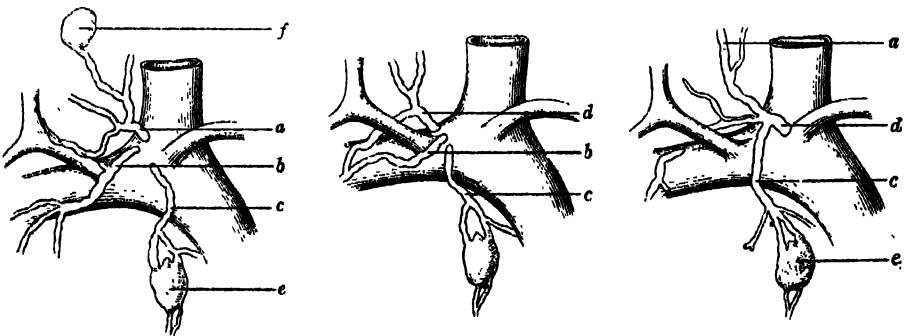


a. Thoracic duct. a'. Cisterna chyli. b, c. Efferent trunks from lateral aortic lymph-glands. d. An efferent vessel which pierces the left crus of the Diaphragm. e, f. Lateral aortic lymph-glands. g. Pre-aortic lymph-glands. h. Retro-aortic lymph-glands. i. Intestinal trunk j. Descending branch from intercostal lymphatics.

ends by opening into the angle of junction of the right subclavian and right internal jugular veins. Its orifice is guarded by two semilunar valves which prevent the passage of venous blood into the duct.

Tributaries.—The right lymphatic duct receives the lymph from the right side of the head and neck through the *right jugular trunk*; from the right upper extremity through the *right subclavian trunk*; from the right side of the thorax, right lung, right side of the heart, and part of the convex surface of the liver, through the *right bronchomediastinal trunk*. These three trunks frequently open separately in the angle of union of the two veins (fig. 688).

FIG. 688.—Terminal collecting trunks of right side. (Poirier and Charpy.)



a. Jugular trunk. b. Subclavian trunk. c. Bronchomediastinal trunk. d. Right lymphatic trunk. e. Lymph-gland of internal mammary chain. f. Lymph-gland of deep cervical chain.

Applied Anatomy.—Blockage of the thoracic duct by mature specimens of the minute parasitic worm *Microfilaria nocturna* gives rise to stasis of the chyle, and to its passage in various abnormal directions on its course past the obstruction. The neighbouring abdominal, renal, and pelvic lymphatics become enlarged, varicose, and tortuous, and

chyle may make its way into the urino (chyluria), the tunica vaginalis (chylocele), the abdominal cavity (chylous ascites), or the pleural cavity (chylous pleural effusion), in consequence of rupture of some of these distended lymphatic vessels.

Gunshot wounds of the chest involving laceration of the thoracic duct and the escape of chyle into the pleural cavity have been described. It appears that if left alone, such lacerations tend to heal and close up spontaneously.

The thoracic duct may be secondarily infected in intestinal or pulmonary tuberculosis, and may contain either miliary tubercles, caseating tuberculous masses, or even tuberculous ulcers. It is often the seat of secondary carcinomatous deposits in cases of cancer of some abdominal viscus, becoming infiltrated throughout until it becomes a stiff moniliform rod as thick as a pencil, with multiple stenoses and dilatations of its lumen; in such cases the left supraclavicular lymph-glands are often infected and enlarged, while the lungs remain free from secondary growths.

LYMPH GLANDS OF THE HEAD AND NECK

1. The lymph-glands of the head (fig. 689) consist of the following groups :

Occipital.

Posterior auricular.

Anterior auricular.

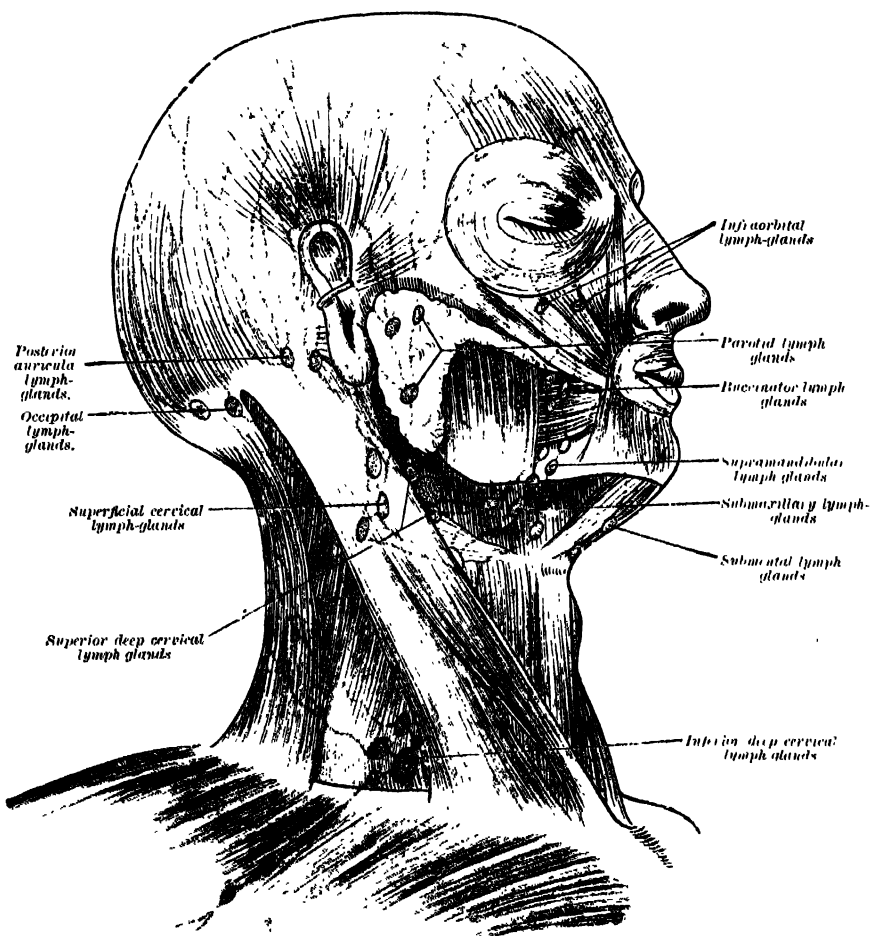
Parotid.

Facial.

Deep facial.

Lingual.

FIG. 689.—Superficial lymph-glands and lymphatic vessels of head and neck.



The occipital lymph-glands, one to three in number, are placed on the back of the head close to the margin of the Trapezius and resting on the insertion of the Semispinalis capitis. Their afferent vessels drain the lymph from the

occipital region of the scalp; their efferents convey it to the superior deep cervical lymph-glands.

The **posterior auricular lymph-glands**, usually two in number, are situated on the mastoid insertion of the Sternocleidomastoideus, beneath the Auricularis posterior. Their afferent vessels drain the posterior part of the temporoparietal region, the upper part of the cranial surface of the auricula or pinna, and the back of the external acoustic meatus; their efferents pass to the superior deep cervical lymph-glands.

The **anterior auricular lymph-glands**, from one to three in number, lie immediately in front of the tragus. Their afferents drain the lateral surface of the auricula and the skin of the adjacent part of the temporal region; their efferents pass to the superior deep cervical lymph-glands.

The **parotid lymph-glands** form two groups, one imbedded in the substance of the parotid salivary gland, and the other, or subparotid group, placed on the lateral wall of the pharynx. Occasionally small lymph-glands are found in the subcutaneous tissue over the parotid salivary gland. The afferents of the subparotid lymph-glands drain the nasal part of the pharynx and the posterior parts of the nasal cavities; their efferents pass to the superior deep cervical lymph-glands. The afferents of the remaining parotid lymph-glands drain the root of the nose, the eyelids, the frontotemporal region, the external acoustic meatus and the tympanic cavity, possibly also the posterior parts of the palate and of the floor of the nasal cavity. Their efferents pass to the superior deep cervical lymph-glands.

The **facial lymph-glands** comprise three groups: (a) *infraorbital*, scattered over the infraorbital region from the groove between the nose and cheek to the zygomatic arch; (b) *buccinator*, one or more on the Buccinator opposite the angle of the mouth; (c) *supramandibular*, on the outer surface of the mandible in front of the Masseter and in contact with the external maxillary artery and anterior facial vein. Their afferents drain the eyelids, the conjunctiva, and the skin and mucous membrane of the nose and cheek; their efferents pass to the anterior auricular and submaxillary lymph-glands.

The **deep facial lymph-glands** are placed beneath the ramus of the mandible, on the outer surface of the Pterygoideus externus, in relation to the internal maxillary artery. Their afferents drain the temporal and infratemporal fossæ, the palate and the nasal part of the pharynx; their efferents pass to the superior deep cervical lymph-glands.

The **lingual lymph-glands** are two or three small nodules lying on the Hyoglossus, and between the Genioglossi. They are merely glandular nodules in the course of the lymphatic vessels of the tongue.

2. The **lymph-glands of the neck** include the following groups:

Retropharyngeal.
Submaxillary.
Submental.

Anterior cervical.
Superficial cervical.
Deep cervical.

The **retropharyngeal lymph-glands** (fig. 691), from one to three in number, lie in the buccopharyngeal fascia, behind the upper part of the pharynx and in front of the arch of the atlas, being separated, however, from the latter by the Longus capitis. Their afferents drain the nasal cavities, the nasal part of the pharynx, and the auditory tubes; their efferents pass to the superior deep cervical lymph-glands.

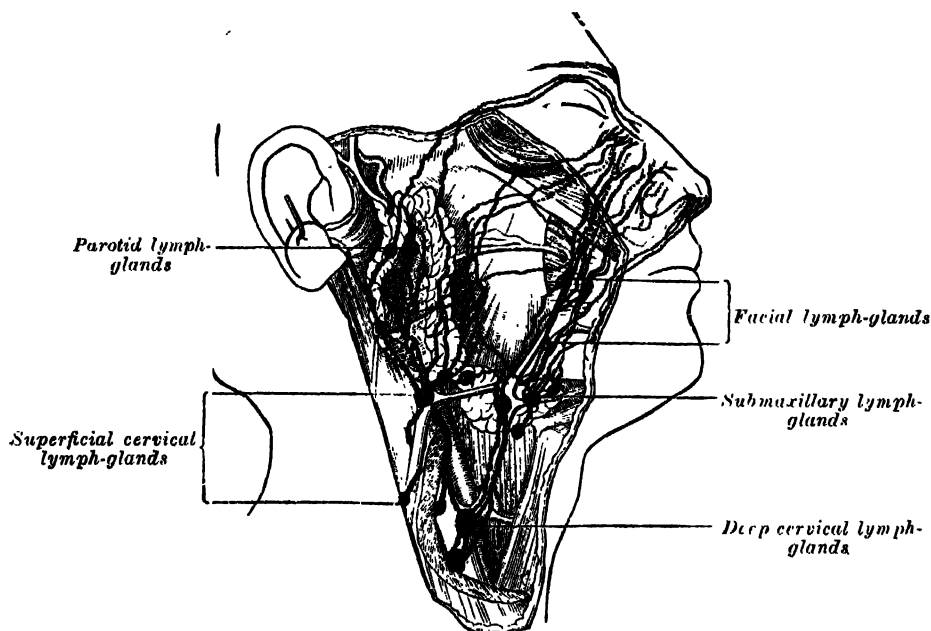
The **submaxillary lymph-glands** (fig. 690), three to six in number, are placed beneath the body of the mandible in the submaxillary triangle, and rest on the superficial surface of the submaxillary salivary gland. One (the *middle lymph-gland of Stahr*) lies on the external maxillary artery as this artery turns over the mandible, and is the most constant of the series; small lymph-glands are sometimes found imbedded in the submaxillary salivary gland or lying on its deep surface. The afferents of the submaxillary lymph-glands drain the medial palpebral commissure, the cheek, the side of the nose, the upper lip, the lateral part of the lower lip, the gums, and the anterior part of the margin of the tongue; efferent vessels from the facial and submental lymph-glands also enter the submaxillary lymph-glands. Their efferent vessels pass to the superior deep cervical lymph-glands.

The **submental or suprahyoid lymph-glands** are placed between the

anterior bellies of the two Digastric muscles. Their afferents drain the central portions of the lower lip and floor of the mouth and the apex of the tongue; their efferents pass partly to the submaxillary lymph-glands and partly to a lymph-gland of the deep cervical group situated on the internal jugular vein at the level of the cricoid cartilage.

The **anterior cervical lymph-glands** are placed in front of the larynx and trachea, and consist of a *superficial* and a *deep* set. The lymph-glands of the superficial set lie alongside the anterior jugular vein, but are inconstant in number and size. The lymph-glands of the deep set comprise: (a) the *infrahyoid lymph-glands* which lie in front of the hyothyroid membrane, and receive their afferents from the neighbourhood of the epiglottis; (b) the *prelaryngeal lymph-glands* which lie on the middle cricothyroid ligament; and (c) the *pretracheal lymph-glands* which are placed in front of the trachea, alongside the inferior thyroid veins. The prelaryngeal and pretracheal groups receive their afferents from the larynx, the thyroid gland, and the cervical part of the trachea; their efferents pass to the deep cervical lymph-glands.

FIG. 690.—Lymphatics of the face. (After Küttner.)



The **superficial cervical lymph-glands** (fig. 689) lie in close relationship with the external jugular vein as it emerges from the parotid gland, and are superficial to the Sternocleidomastoideus. Their afferents drain the parotid region and the lower part of the auricula, while their efferents pass round the anterior margin of the Sternocleidomastoideus to join the superior deep cervical lymph-glands.

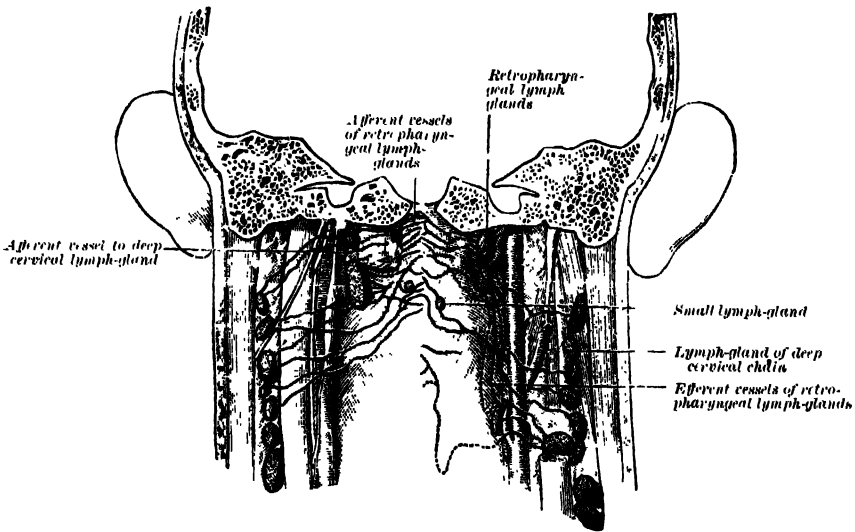
The **deep cervical lymph-glands** (figs. 691, 692) are numerous and of large size; they form a chain along the carotid sheath, lying by the side of the pharynx, œsophagus, and trachea, and extending from the base of the skull to the root of the neck. They are usually described in two groups: (1) the *superior deep cervical lymph-glands* lying under the Sternocleidomastoideus in close relation with the accessory and hypoglossal nerves, and the internal jugular vein, some of the glands lying in front of and others behind the vein; (2) the *inferior deep cervical lymph-glands* extending beyond the posterior margin of the Sternocleidomastoideus into the supraclavicular triangle, where they are closely related to the brachial plexus and subclavian vein. A few minute *paratracheal lymph-glands* are situated alongside the recurrent nerves on the lateral aspects of the trachea and œsophagus. The superior deep cervical lymph-glands drain the occipital portion of the scalp, the auricula,

the back of the neck, a considerable part of the tongue, the larynx, thyroid gland, trachea, nasal part of the pharynx, nasal cavities, palate, and œsophagus. They receive also the efferent vessels from all the other lymph-glands of the head and neck, except those from the inferior deep cervical lymph-glands. The inferior deep cervical lymph-glands drain the back of the scalp and neck, the superficial pectoral region, and part of the arm (p. 721). In addition, they receive vessels from the superior deep cervical lymph-glands. The efferents of the superior deep cervical lymph-glands pass partly to the inferior deep cervical lymph-glands and partly to a trunk which unites with the efferent vessel of the inferior deep cervical lymph-glands and forms the *jugular trunk*. On the right side, this trunk ends in the junction of the internal jugular and subclavian veins; on the left side it joins the thoracic duct.

LYMPHATIC VESSELS OF THE HEAD AND NECK

The *lymphatic vessels of the scalp* are divisible into (a) those of the frontal region, which drain into the anterior auricular and parotid lymph-glands; (b) those of the temporoparietal region, which end in the parotid and posterior auricular lymph-glands; and (c) those of the occipital region, which terminate partly in the occipital lymph-glands and partly in a trunk which runs down along the posterior border of the Sternocleidomastoideus to end in the inferior deep cervical lymph-glands.

FIG. 691.—Lymphatics of the pharynx. (Poirier and Charpy.)



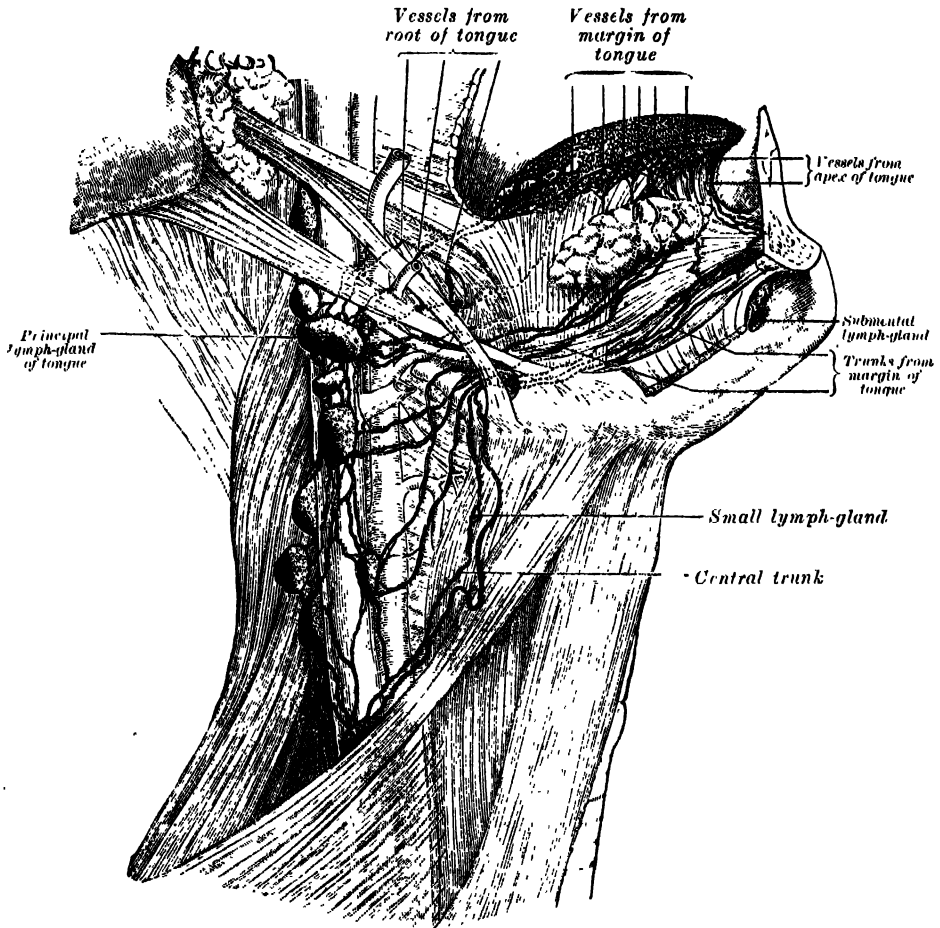
The *lymphatic vessels of the auricula and external acoustic meatus* are also divisible into three groups: (a) an anterior, from the lateral surface of the auricula and anterior wall of the meatus to the anterior auricular lymph-glands; (b) a posterior, from the margin of the auricula, the upper part of its cranial surface, the internal surface and posterior wall of the meatus to the posterior auricular and superior deep cervical lymph-glands; (c) an inferior, from the floor of the meatus and from the lobule of the auricula to the superficial and superior deep cervical lymph-glands.

The *lymphatic vessels of the face* (figs. 689, 690) are more numerous than those of the scalp. Those from the eyelids and conjunctiva terminate partly in the submaxillary, but mainly in the parotid, lymph-glands. The vessels from the posterior part of the cheek also pass to the parotid lymph-glands, while those from the anterior portion of the cheek, the side of the nose, the upper lip, and the lateral portions of the lower lip end in the submaxillary lymph-glands. The deeper vessels from the temporal and infratemporal fossæ pass

to the deep facial and superior deep cervical lymph-glands. The deeper vessels of the cheek and lips end, like the superficial, in the submaxillary lymph-glands. Both superficial and deep vessels of the central part of the lower lip run to the submental lymph-glands.

The *lymphatic vessels of the nasal cavities* can be injected from the subdural and subarachnoid cavities. Those from the anterior parts of the nasal cavities communicate with the lymphatic vessels of the skin of the nose, and end in the submaxillary lymph-glands; those from the posterior two-thirds of the nasal cavities and from the accessory air-sinuses of the nose pass partly to the retropharyngeal and partly to the superior deep cervical lymph-glands.

FIG. 692.—Lymphatics of the tongue. (Poirier.)



Lymphatic vessels of the mouth.—The vessels of the gums pass to the submaxillary lymph-glands; those of the hard palate are continuous in front with those of the upper gum, but run backwards to pierce the Constrictor pharyngis superior, and end in the superior deep cervical and subparotid lymph-glands; those of the soft palate pass backwards and lateralwards and end partly in the retropharyngeal and subparotid, and partly in the superior deep cervical lymph-glands. The vessels of the anterior part of the floor of the mouth go either directly to the inferior lymph-glands of the superior deep cervical group, or indirectly, through the submental lymph-glands; the vessels from the rest of the floor of the mouth pass to the submaxillary and superior deep cervical lymph-glands.

The *lymphatic vessels of the palatine tonsil*, usually three to five in number, pierce the buccopharyngeal fascia and Constrictor pharyngis superior and pass

between the Stylohyoideus and the internal jugular vein to the superior deep cervical lymph-glands. Most of them end in a lymph-gland which lies at the side of the posterior belly of the Digastricus, on the internal jugular vein; occasionally one or two additional vessels run to small lymph-glands on the lateral side of the vein, under cover of the Sternocleidomastoideus.

The *lymphatic vessels of the tongue* (fig. 692) are drained chiefly into the deep cervical lymph-glands lying between the posterior belly of the Digastricus and the superior belly of the Omohyoideus; one gland situated at the bifurcation of the common carotid artery is so intimately associated with these lymphatic vessels that it is known as the *principal lymph-gland of the tongue*. The lymphatic vessels of the tongue may be divided into four groups: (1) apical, from the apex of the tongue to the suprahyoid lymph-glands and principal lymph-gland of the tongue; (2) lateral, from the margin of the tongue, some of which pierce the Mylohyoideus to end in the submaxillary lymph-glands, others pass down on the Hyoglossus to the superior deep cervical lymph-glands; (3) basal, from the region of the papillæ vallatæ to the superior deep cervical lymph-glands; and (4) median, a few of which perforate the Mylohyoideus to reach the submaxillary lymph-glands, while the majority turn round the posterior border of the muscle to enter the superior deep cervical lymph-glands; some of the median vessels drain into the submaxillary lymph-glands of the opposite side.

The *lymphatic vessels of the skin and muscles of the neck* pass to the deep cervical lymph-glands. From the upper part of the *pharynx* the lymphatic vessels pass to the retropharyngeal lymph-glands; from the lower part to the deep cervical lymph-glands. From the *larynx* two sets of vessels arise, an upper and a lower. The vessels of the upper set pierce the hyothyroid membrane and join the superior deep cervical lymph-glands. Of the lower set, some pierce the conus elasticus and join the pretracheal and prelaryngeal lymph-glands; others run between the cricoid cartilage and first tracheal ring and enter the inferior deep cervical lymph-glands. The lymphatic vessels of the *thyroid gland* consist of an upper set, which accompanies the superior thyreoid artery and enters the superior deep cervical lymph-glands, and a lower, which runs partly to the pretracheal lymph-glands and partly to the small paratracheal lymph-glands which accompany the recurrent nerves. The paratracheal lymph-glands also receive lymphatic vessels from the cervical portion of the trachea.

Applied Anatomy.—The superficial and deep cervical lymph-glands often become infected from inflammatory conditions about the mouth, teeth, tonsil and pharynx. When suppuration occurs in the deep group it is apt to spread widely beneath the deep cervical fascia unless relieved by early incision.

The cervical lymph-glands are very frequently the seat of tuberculous disease. This condition may be set up by some lesion in those parts from which they receive their lymph. It is very desirable for the surgeon, in dealing with these cases, to possess a knowledge of the relation of the respective groups of lymph-glands to important structures, as in order to eradicate them by operation a long and difficult dissection may be required.

The same can also be said of these lymph-glands when they become infiltrated with carcinomatous growth secondary to disease of the lip, tongue, palate, or pharynx. At times it will be found necessary to remove a portion of the internal jugular vein, previously ligatured, with the mass of glands.

LYMPH-GLANDS OF THE UPPER EXTREMITY

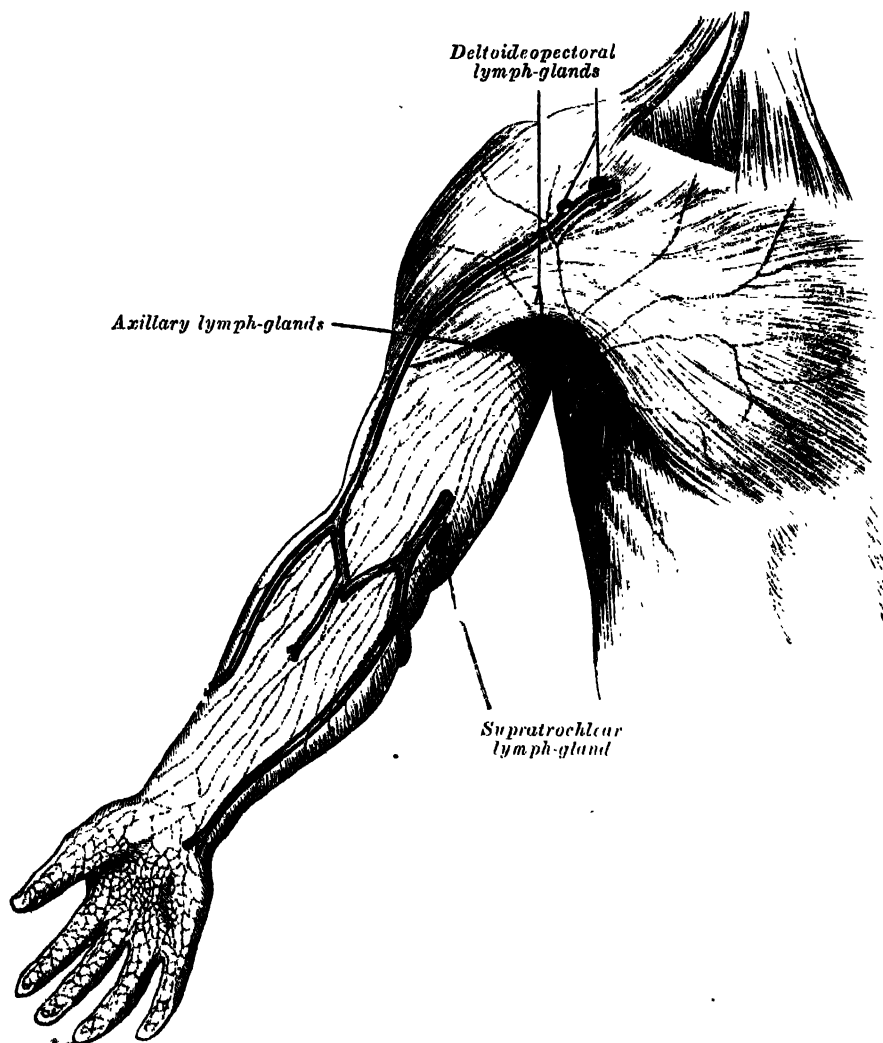
7X The lymph-glands of the upper extremity are divided into two sets, *superficial* and *deep*.

The *superficial lymph-glands* (fig. 693) are few and of small size. One or two *supratrochlear* lymph-glands are placed above the medial epicondyle of the humerus, on the medial side of the basilic vein. Their afferents drain the middle, ring, and little fingers, the medial portion of the hand, and the superficial area over the ulnar side of the forearm; these vessels are, however, in free communication with the other lymphatic vessels of the forearm. Their efferents accompany the basilic vein and join the deeper vessels. One or two

deltoideopectoral lymph-glands are found beside the cephalic vein, between the Pectoralis major and Deltoideus, immediately below the clavicle. They are situated in the course of a collecting trunk which drains the lateral side of the arm and forearm.

The **deep lymph-glands** are chiefly grouped in the axilla, although a few may be found in the forearm, in the course of the radial, ulnar, and interosseous vessels, and in the arm along the medial side of the brachial artery.

FIG. 698.—The superficial lymph-glands and lymphatic vessels of the upper extremity.



The **axillary lymph-glands** (fig. 694) are of large size; they vary from twenty to thirty in number, and may be arranged in the following groups:

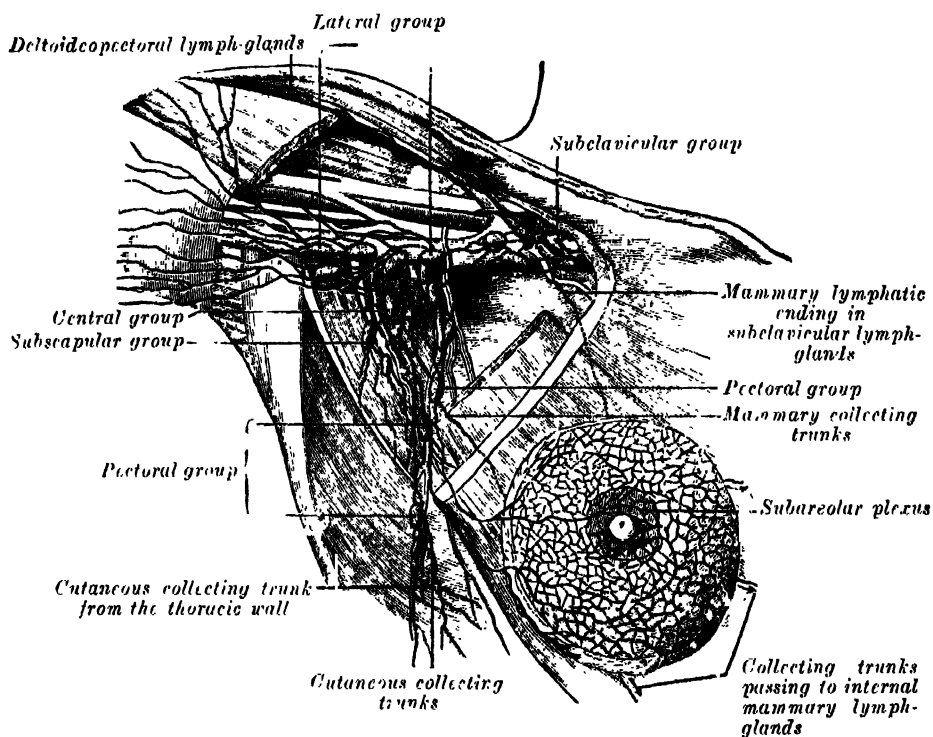
1. A lateral group of from four to six lymph-glands lies in relation to the medial and posterior aspects of the axillary vein; the afferents of this group drain the whole arm with the exception of that portion whose lymphatic vessels accompany the cephalic vein. The efferent vessels pass partly to the central and subclavicular groups of axillary lymph-glands, and partly to the inferior deep cervical lymph-glands.

2. An anterior or pectoral group, consisting of four or five lymph-glands, lies along the lower border of the Pectoralis minor, in relation with the lateral thoracic artery. Its afferents drain the skin and muscles of the anterior and

lateral thoracic walls, and the central and lateral parts of the mamma; its efferents pass partly to the central, and partly to the subclavicular groups of axillary lymph-glands.

3. A posterior or subscapular group of six or seven lymph-glands is placed along the lower margin of the posterior wall of the axilla in the course of the subscapular artery. The afferents of this group drain the skin and muscles of the lower part of the back of the neck and of the posterior thoracic wall; their efferents pass to the central group of axillary lymph-glands.

FIG. 694.—Lymphatics of the mamma, and the axillary lymph-glands (semi-diagrammatic). (Poirier and Charpy.)



4. A central or intermediate group of three or four large lymph-glands is imbedded in the adipose tissue near the base of the axilla. Its efferents are the efferent vessels of all the preceding groups of axillary lymph-glands: its efferents pass to the subclavicular group of lymph-glands.

5. A medial or subclavicular group of six to twelve lymph-glands is situated partly posterior to the upper portion of the Pectoralis minor and partly above the upper border of this muscle. The only direct territorial afferents of this group are those which accompany the cephalic vein and one which drains the upper peripheral part of the mamma, but it receives the efferents of all the other axillary lymph-glands. The efferent vessels of this group unite to form the subclavian trunk, which opens either directly into the junction of the internal jugular and subclavian veins or into the jugular lymphatic trunk: on the left side it may end in the thoracic duct. A few efferents from the subclavicular group usually pass to the inferior deep cervical lymph-glands.

Applied Anatomy.—Enlargement of the axillary lymph-glands is very often found in malignant disease and also in infective processes implicating the upper part of the back and shoulder, the front of the chest and mamma, the upper part of the front and side of the abdomen, or the hand, forearm, and arm.

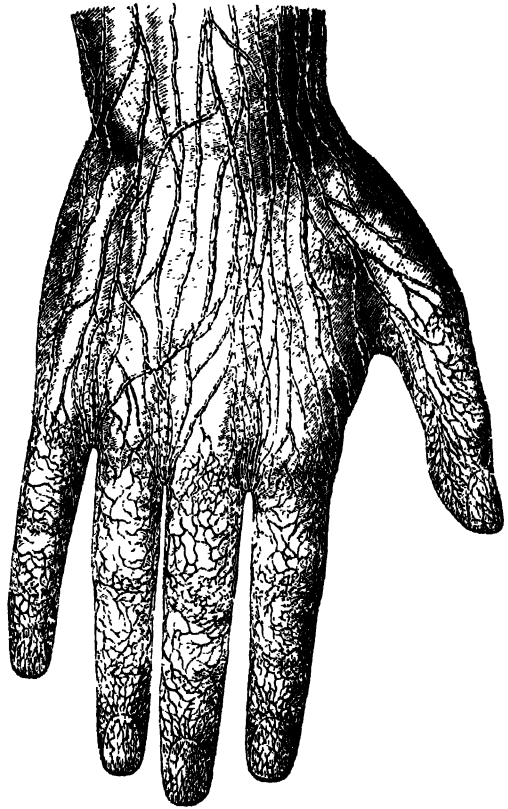
LYMPHATIC VESSELS OF THE UPPER EXTREMITY

The *lymphatic vessels of the upper extremity* consist of two sets, superficial and deep.

The *superficial lymphatic vessels* (fig. 695) commence in the lymphatic plexus which everywhere pervades the skin; the meshes of the plexus are much finer in the palm and on the flexor aspects of the digits than elsewhere. The digital plexuses are drained by a pair of vessels which run on the sides of each digit, and incline backwards to reach the dorsum of the hand. From the dense plexus of the palm, vessels pass in different directions, viz. upwards towards the wrist, downwards to join the digital vessels, medialwards to join the vessels on the ulnar border of the hand, and lateralwards to those on the thumb. Several vessels from the central part of the plexus unite to form a trunk, which passes round the metacarpal bone of the index finger to join the vessels on the back of that digit and on the back of the thumb. As the lymphatic vessels run upwards in front of and behind the wrist, they are collected into groups, which accompany the cephalic, median antibrachial, and basilic veins in the forearm. A few of those on the ulnar side end in the supratrochlear lymph-glands, but the majority pass directly to the lateral group of axillary lymph-glands. Some of the vessels on the radial side are collected into a trunk which ascends with the cephalic vein to the deltoideopectoral lymph-glands; the efferents from this group pass either to the sub-clavicular axillary lymph-glands or to the inferior deep cervical lymph-glands.

The *deep lymphatic vessels* accompany the deep blood-vessels. In the forearm, they consist of four sets, corresponding with the radial, ulnar, volar interosseous, and dorsal interosseous arteries; they communicate at intervals with the superficial lymphatic vessels, and some of them end in the lymph-glands which are occasionally found beside the arteries. In their course upwards, a few end in the supratrochlear lymph-glands, but most of them pass to the lateral group of axillary lymph-glands. •

FIG. 695.—Lymphatic vessels of the dorsal surface of the hand. (Sappey.)



R

LYMPH-GLANDS OF THE LOWER EXTREMITY

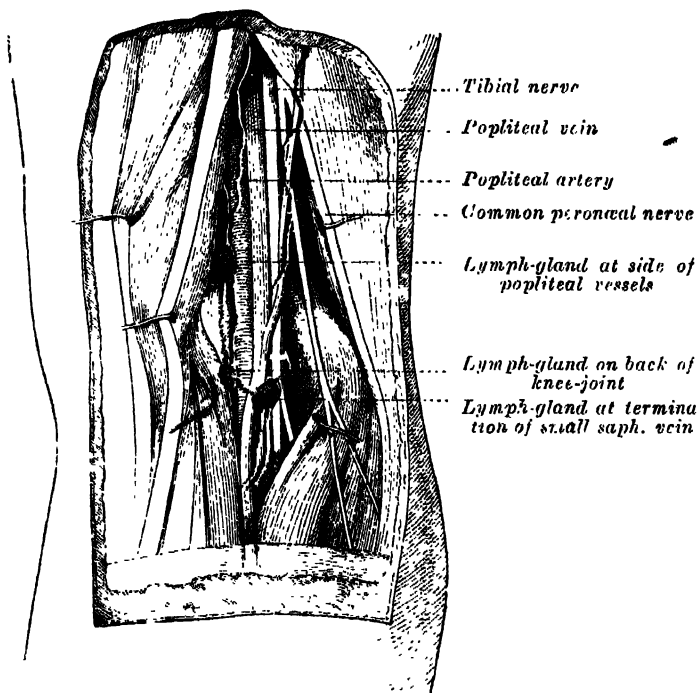
The *lymph-glands of the lower extremity* consist of three sets:—the anterior tibial, the popliteal and the inguinal.

The *anterior tibial lymph-gland* is small and inconstant; it lies on the interosseous membrane in relation to the upper part of the anterior tibial vessels.

The *popliteal lymph-glands* (fig. 696), small in size and six or seven in number, are imbedded in the fat contained in the popliteal fossa. One lies

immediately beneath the popliteal fascia, near the terminal part of the small saphenous vein, and drains the region from which this vein derives its tributaries. Another is placed between the popliteal artery and the posterior surface of the knee-joint; it receives the lymphatic vessels from the knee-joint together with those which accompany the genicular arteries. The other lymph-glands lie at the sides of the popliteal vessels, and receive as afferents the trunks which accompany the anterior and posterior tibial vessels. The efferents of the popliteal lymph-glands pass almost entirely alongside the femoral vessels to the deep subinguinal lymph-glands, but a few may accompany the great saphenous vein, and end in the superficial subinguinal lymph-glands.

FIG. 696.—Lymph-glands of popliteal fossa. (Poirier and Charpy.)



The inguinal lymph-glands (fig. 697), from twelve to twenty in number, are situated at the upper part of the femoral triangle. They may be divided into two groups by a horizontal line at the level of the termination of the great saphenous vein; those lying above this line are termed the superficial inguinal lymph-glands, and those below it the subinguinal lymph-glands, the latter group consisting of a superficial and a deep set.

The *superficial inguinal lymph-glands* form a chain immediately below the inguinal ligament. They receive as afferents the lymphatic vessels from the skin of the penis, scrotum, perinæum, buttock, and abdominal wall below the level of the umbilicus; they also receive lymphatic vessels from the anal canal and from the mucous membrane of the anterior part of the urethra.

The *superficial subinguinal lymph-glands* are placed on either side of the upper part of the great saphenous vein; their afferents consist chiefly of the superficial lymphatic vessels of the lower extremity, except the back and lateral side of the calf of the leg, but they also receive some of the vessels which drain the skin of the penis, scrotum, perinæum, and buttock.

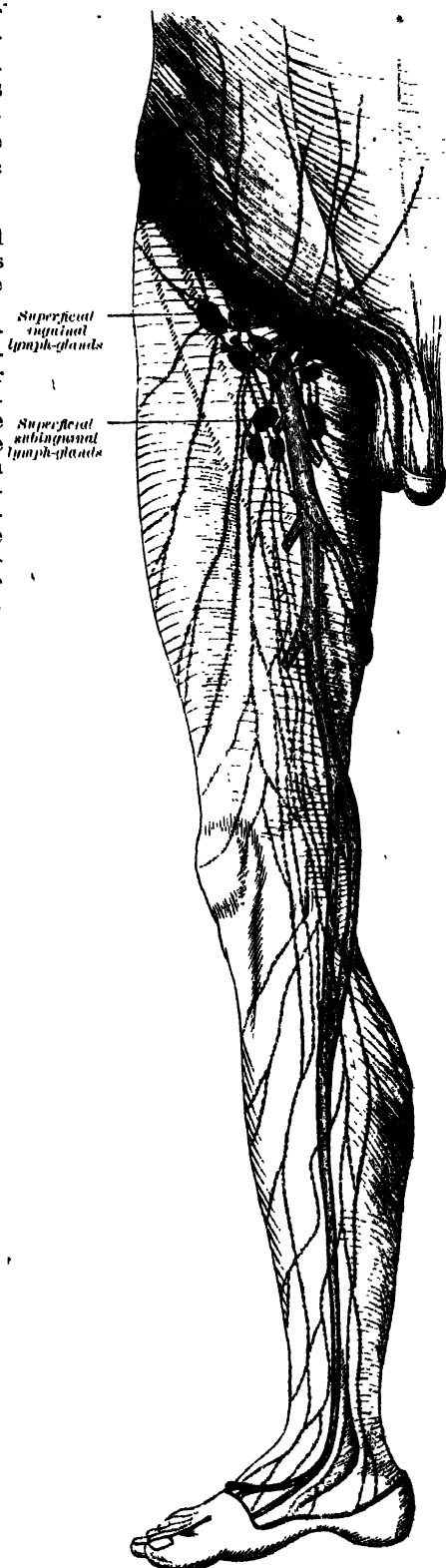
The *deep subinguinal lymph-glands* vary from one to three in number, and are placed under the fascia lata, on the medial side of the femoral vein. When three are present, the lowest is situated just below the junction of the great saphenous and femoral veins, the middle in the femoral canal, and the highest in the lateral part of the femoral ring. The middle one is the most inconstant,

but the highest, the *lymph-gland of Cloquet or Rosenmüller*, is also frequently absent. They receive as afferents the deep lymphatic vessels which accompany the femoral vessels, the lymphatic vessels from the glans penis (vel clitoridis), and also some of the efferents from the superficial subinguinal lymph-glands; their efferents pass through the femoral canal to the external iliac lymph-glands.

Applied Anatomy.—Inflammation and suppuration of the popliteal lymph-glands are most commonly due to a sore on the lateral side of the heel.

The inguinal and subinguinal lymph-glands frequently become enlarged in diseases implicating the parts from which their lymphatic vessels originate. Thus in malignant or syphilitic affections of the prepuce and penis, or labia majora, in cancer of the scrotum, in abscess in the perineum, or in similar diseases affecting the skin and superficial structures in those parts, or the sub-umbilical part of the abdominal wall, or the gluteal region, the upper group of lymph-glands is almost invariably enlarged, the lower groups being implicated in diseases affecting the lower limb.

FIG. 697.—The superficial lymph-glands and lymphatic vessels of the lower extremity.



LYMPHATIC VESSELS OF THE LOWER EXTREMITY

The *lymphatic vessels of the lower extremity* consist of two sets, superficial and deep, and in their distribution correspond closely with the veins.

The *superficial lymphatic vessels* lie in the superficial fascia, and are divisible into two groups: a medial, which follows the course of the great saphenous vein; and a lateral, which accompanies the small saphenous vein. The vessels of the *medial group* (fig. 697) are larger and more numerous than those of the lateral group, and commence on the tibial side and dorsum of the foot; they ascend in front of and behind the medial malleolus, run up the leg with the great saphenous vein, pass with it behind the medial condyle of the femur, and accompany it to the groin, where they end in the subinguinal group of superficial lymph-glands. The vessels of the *lateral group* arise from the fibular side of the foot; some ascend in front of the leg, and cross the tibia below the knee to join the lymphatics on the medial side of the thigh; others pass behind the lateral malleolus, and, accompanying the small saphenous vein, enter the popliteal lymph-glands.

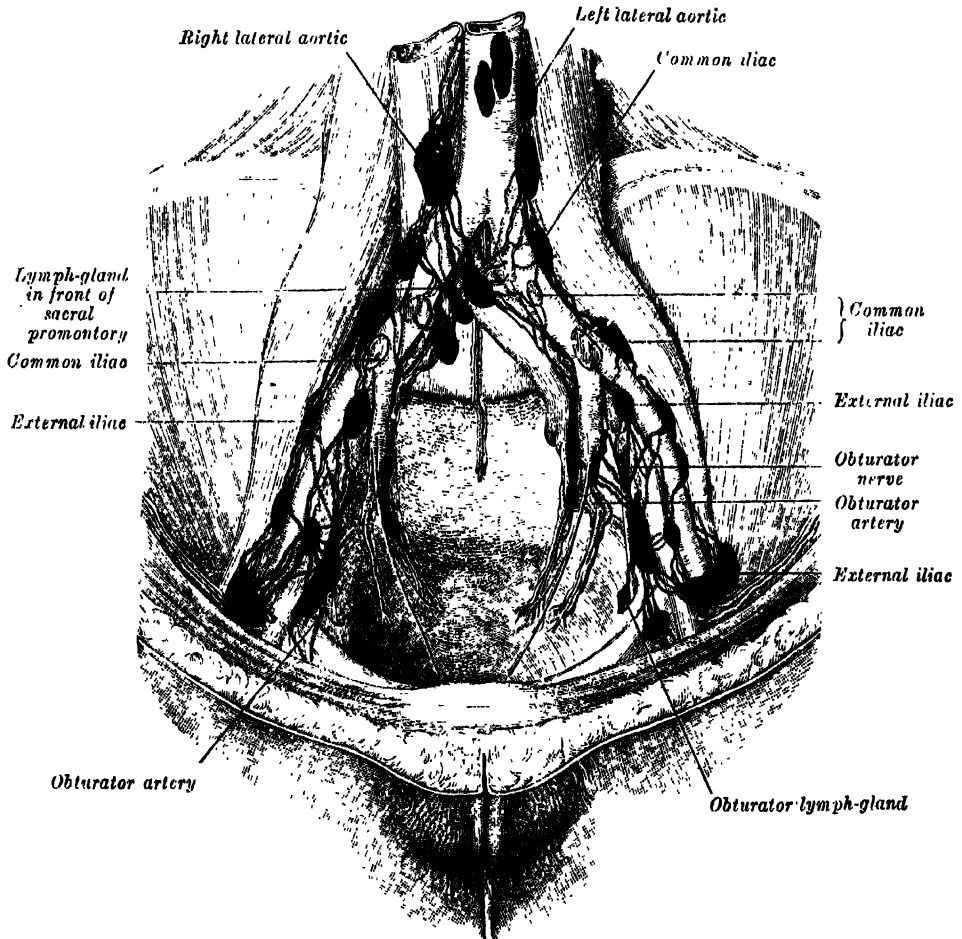
The *deep lymphatic vessels* are few in number, and accompany the deep blood-vessels. In the leg, they consist of three sets, anterior tibial, posterior tibial, and peroneal, which accompany the corresponding blood-vessels, two or three with each artery; they enter the popliteal lymph-glands.

The deep lymphatic vessels of the gluteal and ischial regions follow the course of the corresponding blood-vessels. Those accompanying the superior gluteal vessels end in a lymph-gland which lies on the intrapelvic portion of the superior gluteal artery, near the upper border of the greater sciatic foramen. Those following the inferior gluteal vessels traverse one or two small lymph-glands which lie below the Piriformis muscle, and end in the hypogastric lymph-glands.

LYMPH-GLANDS OF THE ABDOMEN AND PELVIS

The lymph-glands of the abdomen and pelvis may be divided, from their situations, into: 1. *parietal*, lying behind the peritoneum and in close association with the larger blood-vessels; and 2. *visceral*, which are found in relation to the visceral arteries.

FIG. 698.—The parietal lymph-glands of the pelvis. (Cunéo and Marcille.)

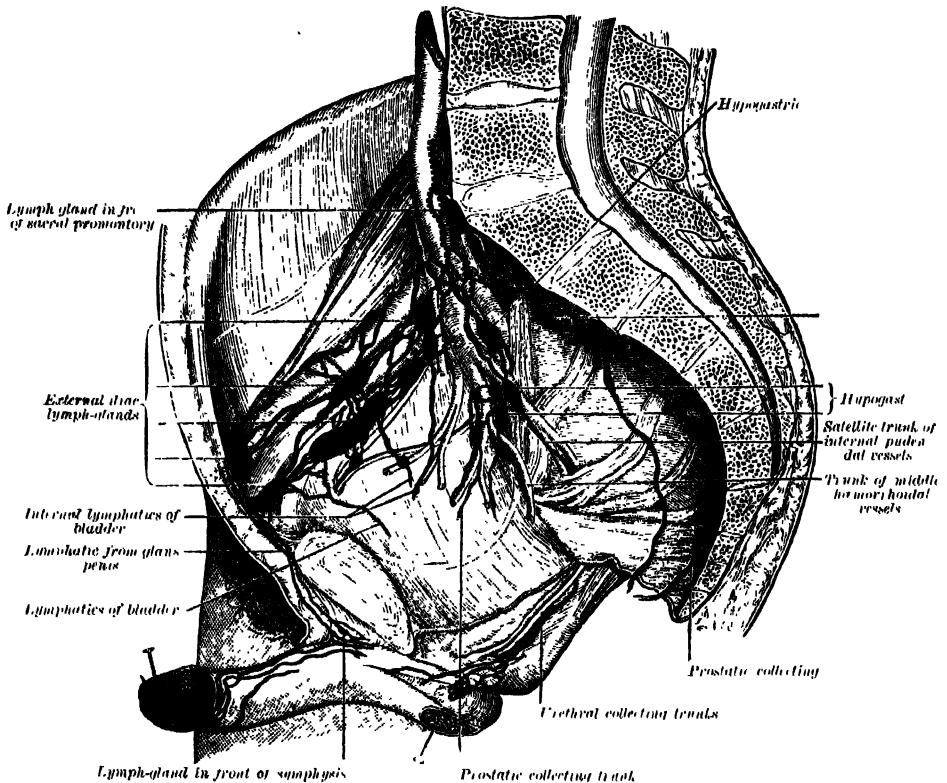


1. The **parietal lymph-glands** (figs. 698, 699) include the following groups:

External iliac.	Iliac circumflex.	Lumbar	Lateral aortic.
Common iliac.	Hypogastric.		Pre-aortic.
Inferior epigastric.	Sacral.		Retro-aortic.

The external iliac lymph-glands, from eight to ten in number, lie along the external iliac vessels. They are arranged in three groups, one on the lateral, another on the medial, and a third on the anterior aspect of the vessels; the third group is, however, sometimes absent. Their principal afferents are derived from the inguinal and subinguinal lymph-glands, the deep lymphatic vessels of the abdominal wall below the umbilicus and of the adductor region of the thigh, and the lymphatic vessels from the glans penis vel clitoridis, the membranous urethra, the prostate, the fundus of the urinary bladder, the cervix uteri, and upper part of the vagina.

FIG. 699.—Iliopelvic lymph-glands (lateral view). (Cunéo and Marcille.)



The common iliac lymph-glands, four to six in number, are grouped behind and on the sides of the common iliac artery, one or two (subaortic) being placed below the bifurcation of the aorta, in front of the fifth lumbar vertebra. They drain chiefly the hypogastric and external iliac lymph-glands, and their efferents pass to the lateral aortic lymph-glands.

The inferior epigastric lymph-glands, three or four in number, are placed alongside the lower portions of the inferior epigastric vessels.

The iliac circumflex lymph-glands, two to four in number, lie along the course of the deep iliac circumflex vessels; they are sometimes absent.

The hypogastric lymph-glands (fig. 699) surround the hypogastric vessels, and receive the lymphatic vessels corresponding to the distribution of the branches of the hypogastric artery, i.e. they receive lymphatic vessels from all the pelvic viscera, from the deeper parts of the perinæum, including the membranous and cavernous portions of the urethra, and from the buttock and back of the thigh. An *obturator lymph-gland* is sometimes present in the upper part of the obturator foramen.

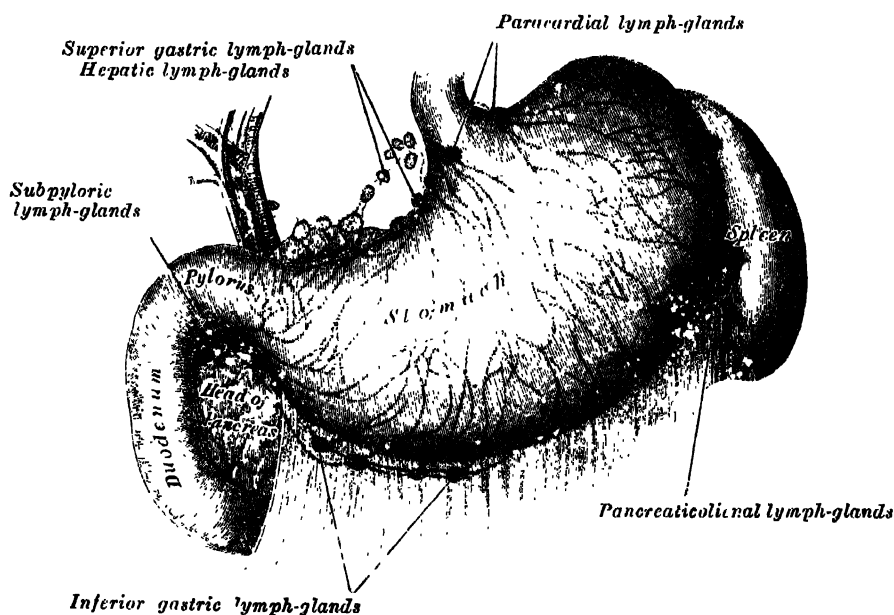
The sacral lymph-glands are placed in the concavity of the sacrum, in relation to the middle and lateral sacral arteries; they receive lymphatic vessels from the rectum and posterior wall of the pelvis.

The efferents of the hypogastric and sacral groups end in the common iliac lymph-glands.

The **lumbar lymph-glands** are very numerous, and consist of right and left lateral aortic, pre-aortic, and retro-aortic groups.

The *right lateral aortic lymph-glands* are situated partly in front of the inferior vena cava, near the termination of the renal vein, and partly behind it on the origin of the Psoas major, and on the right crus of the Diaphragm. The *left lateral aortic lymph-glands* form a chain on the left side of the abdominal aorta in front of the origin of the Psoas major and left crus of the Diaphragm. The lymph-glands on either side receive (a) the efferents of the common iliac lymph-glands; (b) the lymphatics from the testis in the male and from the ovary, uterine tube, and body of the uterus in the female; (c) the lymphatics from the kidney and suprarenal gland; and (d) the lymphatics draining the lateral abdominal muscles and accompanying the lumbar veins. Most of

FIG. 700.—Lymphatics of stomach, &c. (Jamieson and Dobson.)



the efferent vessels of the lateral aortic lymph-glands converge to form the *right and left lumbar trunks* which join the cisterna chyli, but some enter the pre- and retro-aortic lymph-glands, and others pierce the crura of the Diaphragm to join the lower end of the thoracic duct. The *pre-aortic lymph-glands* lie in front of the aorta, and may be divided into *celiac*, *superior mesenteric*, and *inferior mesenteric* groups, arranged around the origins of the corresponding arteries. They receive a few vessels from the lateral aortic lymph-glands, but their principal afferents are derived from the viscera supplied by the three arteries with which they are associated. Some of their efferents pass to the retro-aortic lymph-glands, but the majority unite to form the *intestinal trunk*, which enters the cisterna chyli. The *retro-aortic lymph-glands* are placed below the cisterna chyli, on the bodies of the third and fourth lumbar vertebrae. They receive lymphatic vessels from the lateral and pre-aortic lymph-glands, while their efferents end in the cisterna chyli.

2. The **visceral lymph-glands** are associated with the branches of the celiac, superior and inferior mesenteric arteries. Those related to the branches of the celiac artery form three sets, gastric, hepatic, and pancreaticocolical.

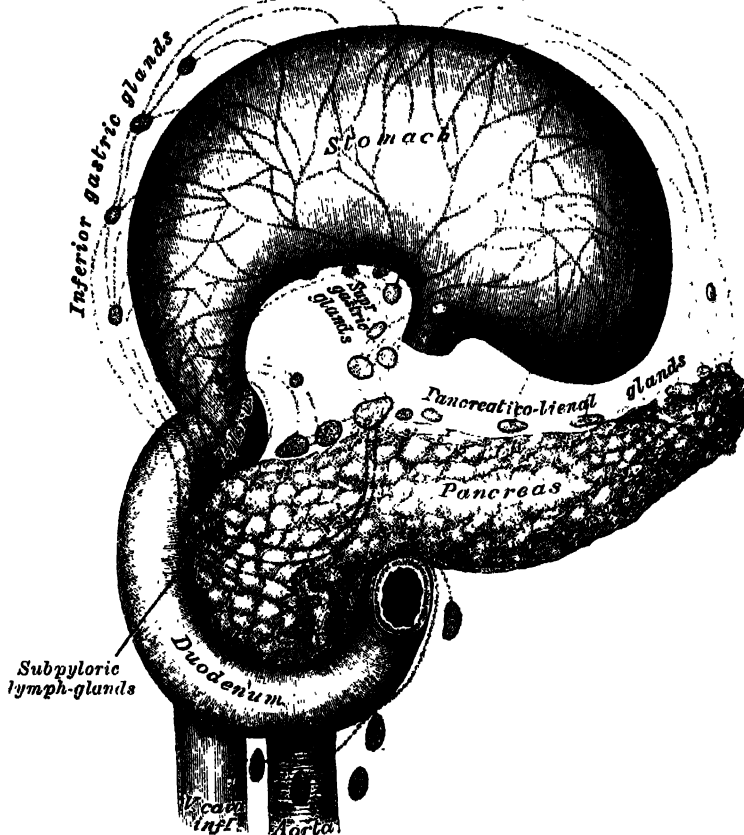
The **gastric lymph-glands** (figs. 700, 701) consist of two sets, superior and inferior.

The **superior gastric lymph-glands** accompany the left gastric artery and are divisible into three groups, viz.: (a) *upper*, on the stem of the artery; (b) *lower*,

accompanying the descending branches of the artery along the cardiac half of the lesser curvature of the stomach, between the two layers of the lesser omentum ; and (c) *paracardial*, disposed in a manner comparable to a chain of beads around the neck of the stomach (Jamieson and Dobson).^{*} They receive their afferents from the stomach, and also some vessels from the pylorus ; their efferents pass to the coeliac group of pre-aortic lymph-glands.

The **inferior gastric lymph-glands**, four to seven in number, lie between the two layers of the greater omentum along the pyloric half of the greater curvature of the stomach. They receive afferents from the stomach ; their efferents mostly pass to the subpyloric lymph-glands.

FIG. 701.—Lymphatics of stomach, &c. The stomach has been turned upwards. (Jamieson and Dobson.)



The **hepatic lymph-glands** (fig. 700) consist of the following groups : (a) *hepatic*, on the stem of the hepatic artery, and extending upwards along the common bile-duct, between the two layers of the lesser omentum, as far as the porta hepatis ; one member of this group, the *cystic lymph-gland*, is placed near the neck of the gall-bladder ; (b) *subpyloric*, four or five in number, in close relation to the bifurcation of the gastroduodenal artery, in the angle between the superior and descending parts of the duodenum ; an outlying member of this group is sometimes found above the duodenum on the right gastric (pyloric) artery. The lymph-glands of the hepatic chain receive afferents from the stomach, duodenum, liver, gall-bladder, and pancreas ; their efferents join the coeliac group of pre-aortic lymph-glands.

The **pancreaticolienal lymph-glands** (fig. 701) accompany the lienal (splenic) artery, and are situated in relation to the posterior surface and upper border of the pancreas ; one or two members of this group are found in the

^{*} *Lancet*, April 20 and 27, 1907.

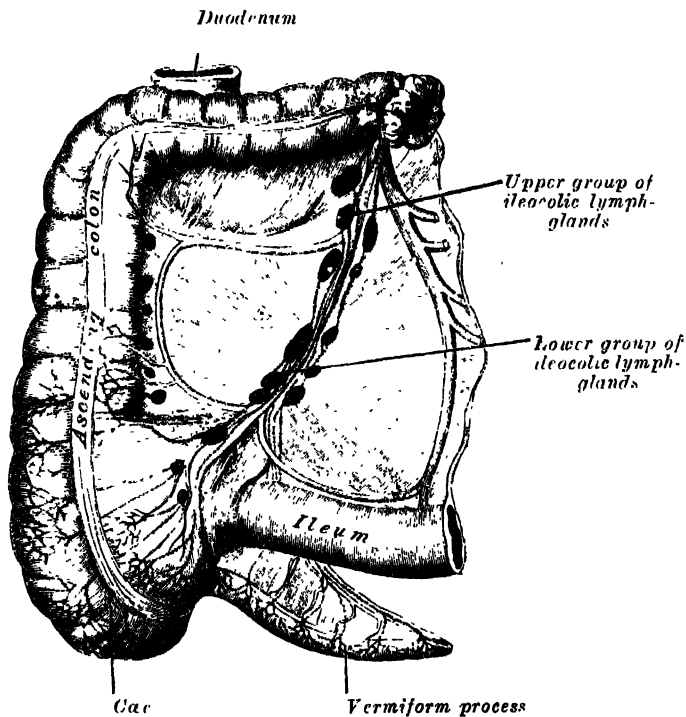
gastrolenal ligament (Jamieson and Dobson, *loc. cit.*). Their afferents are derived from the stomach, spleen, and pancreas; their efferents join the coeliac group of pre-aortic lymph-glands.

The superior mesenteric lymph-glands may be divided into three principal groups: mesenteric, ileocolic, and mesocolic.

The *mesenteric lymph-glands* lie between the layers of the mesentery. They vary from one hundred to one hundred and fifty in number, and consist of three sets, viz.: one lying close to the wall of the small intestine, amongst the terminal twigs of the superior mesenteric artery; a second, in relation to the loops and primary branches of the jejunal and ileal vessels; and a third along the upper part of the trunk of the superior mesenteric artery.

Applied Anatomy.—Enlargement of the mesenteric lymph-glands is seen in most diseased conditions of the intestinal tract, and is well marked in enteric fever, tuberculous ulceration or malignant growths of the bowel. The enlarged lymph-glands can often be palpated through the wall of the abdomen.

FIG. 702.—The lymphatics of cæcum and vermiform process, from the front. (Jamieson and Dobson.)



The *ileocolic lymph-glands* (figs. 702, 703), from ten to twenty in number, form a chain around the ileocolic artery, but show a tendency to subdivision into two groups, one near the duodenum and another on the lower part of the trunk of the artery. Where the vessel divides into its terminal branches the chain is broken up into several groups, viz.: (a) *ileal*, in relation to the ileal branch of the artery; (b) *anterior ileocolic*, usually of three glands, in the ileocolic fold, near the wall of the cæcum; (c) *posterior ileocolic*, mostly placed in the angle between the ileum and the colon, but partly lying behind the cæcum at its junction with the ascending colon; (d) a single gland in the mesenteriole of the vermiform process; (e) *right colic*, along the medial side of the ascending colon.

The *mesocolic lymph-glands* are numerous, and lie between the layers of the transverse mesocolon, in close relation to the transverse colon; they are best developed in the neighbourhood of the right and left colic flexures. One or two small lymph-glands are occasionally seen along the trunk of the right

colic artery, and others are found in relation to the trunk and branches of the middle colic artery.

The superior mesenteric lymph-glands receive afferents from the jejunum, ileum, cæcum, vermiform process, and the ascending and transverse parts of the colon; their efferents pass to the superior mesenteric group of pre-aortic lymph-glands.

The inferior mesenteric lymph-glands (fig. 704) consist of: (a) small glands on the branches of the left colic and sigmoid arteries; (b) a group in the sigmoid mesocolon, around the superior hæmorrhoidal artery; and (c) a *pararectal* group in contact with the muscular coat of the rectum. They drain the descending and sigmoid parts of the colon and the upper part of the rectum; their efferents pass to the inferior mesenteric group of pre-aortic lymph-glands.

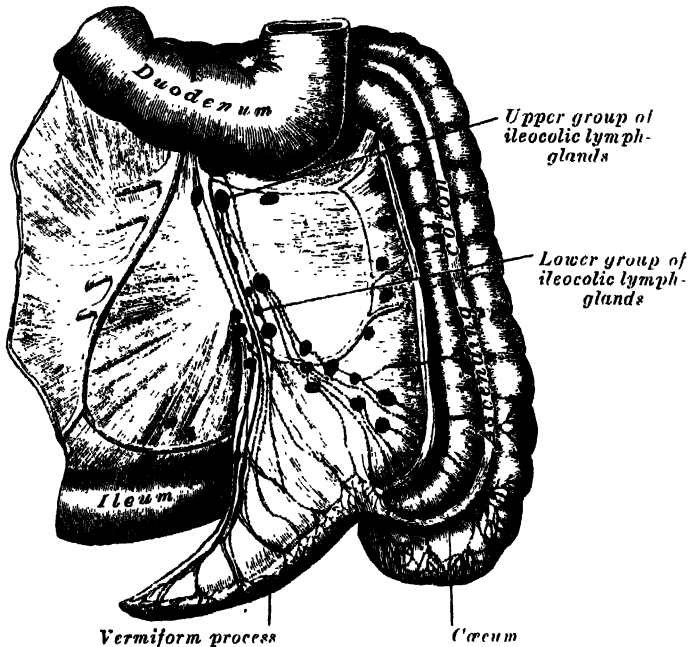
LYMPHATIC VESSELS OF THE ABDOMEN AND PELVIS

The lymphatic vessels of the abdomen and pelvis may be divided into 1. parietal and 2. visceral.

1. The **parietal lymphatic vessels** consist of two sets, superficial and deep.

The *superficial lymphatic vessels* follow the course of the superficial blood-vessels, and converge to the superficial inguinal lymph-glands; those derived

FIG. 703—The lymphatics of the cæcum and vermiform process, from behind.
(Jamieson and Dobson.)



from the skin of the front of the abdomen below the umbilicus follow the course of the superficial epigastric vessels, and those from the sides of the lumbar part of the abdominal wall pass along the crest of the ilium, with the superficial iliac circumflex vessels. The superficial lymphatic vessels of the gluteal region turn horizontally round the buttock, and join the superficial inguinal and subinguinal lymph-glands.

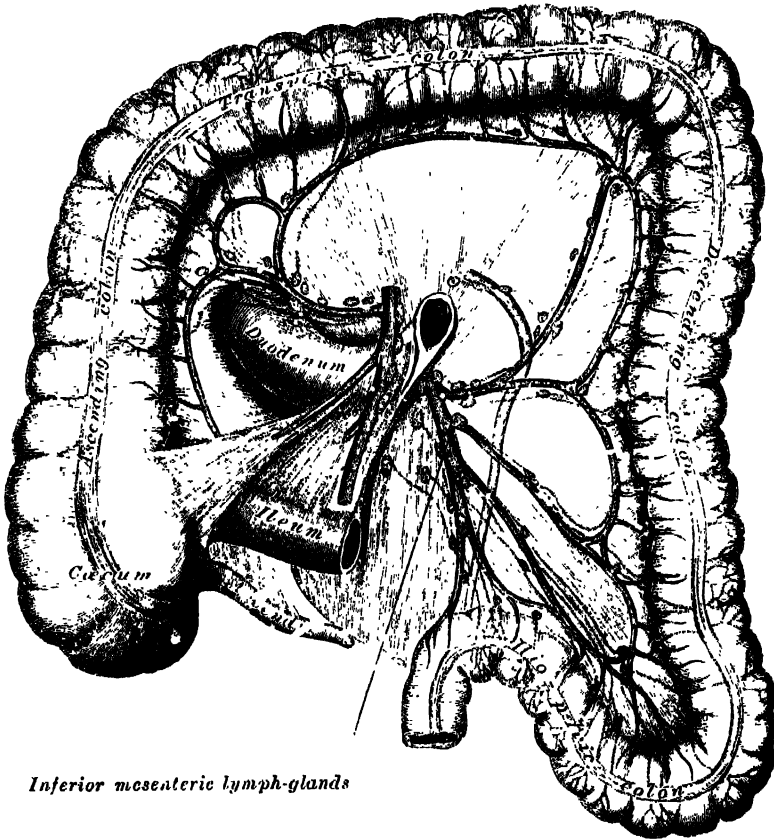
The *deep lymphatic vessels* run alongside the principal blood-vessels. Those of the parietes of the pelvis, which accompany the superior and inferior gluteal

and obturator vessels, follow the course of the hypogastric artery, and ultimately join the lateral aortic lymph-glands.

Lymphatic vessels of the perinæum and external genitals.—The lymphatic vessels of the perinæum, of the skin of the penis, and of the scrotum (or vulva) follow the course of the external pudendal vessels, and end in the superficial inguinal and subinguinal lymph-glands. Those of the glans penis (vel clitoridis) terminate partly in the deep subinguinal lymph-glands and partly in the external iliac lymph-glands.

2. The **visceral lymphatic vessels** consist of: (1) those of the sub-diaphragmatic portion of the digestive tube and its associated glands, the

FIG. 704.—Lymphatics of colon. (Jamieson and Dobson.)



Inferior mesenteric lymph-glands

liver and pancreas; (2) those of the spleen and suprarenal glands; (3) those of the urinary organs; (4) those of the reproductive organs.

(1) The *lymphatic vessels of the subdiaphragmatic portion of the digestive tube* are situated partly in the mucous membrane and partly in the sero-muscular coats, but as the former system drains into the latter, the two may be considered as one.

The *lymphatic vessels of the stomach* (figs. 700, 701) are continuous at the cardiac orifice with those of the œsophagus, and at the pylorus with those of the duodenum. They mainly follow the blood-vessels, and may be arranged in four sets. The first set accompanies the branches of the left gastric artery, receives tributaries from a large area on either surface of the stomach, and terminates in the superior gastric lymph-glands. Those of the second set drain the fundus and body of the stomach on the left of a line drawn vertically from the œsophagus; they accompany, more or less closely, the short gastric and left gastro-epiploic arteries, and end in the pancreaticocolic lymph-glands.

The third set drains the right part of the greater curvature as far as the pyloric portion, and ends in the inferior gastric lymph-glands, the efferents of which pass to the subpyloric group. Those of the fourth set drain the pyloric portion and pass to the hepatic, subpyloric, and superior gastric lymph-glands.

The *lymphatic vessels of the duodenum* consist of an anterior and a posterior set, which open into a series of small *pancreaticoduodenal lymph-glands*, on the anterior and posterior aspects of the groove between the head of the pancreas and the duodenum. The efferents of these glands run in two directions, upwards to the hepatic lymph-glands, and downwards to the pre-aortic lymph-glands around the origin of the superior mesenteric artery.

The *lymphatic vessels of the jejunum and ileum* are termed *lacteals*, from the milk-white fluid they contain during intestinal digestion. They run between the layers of the mesentery and enter the mesenteric glands, the efferents from which end in the pre-aortic lymph-glands.

The *lymphatic vessels of the vermiform process and cæcum* (figs. 702, 703) are numerous, since in the wall of the vermiform process there is a large amount of adenoid tissue. From the body and tail of the vermiform process eight to fifteen vessels ascend between the layers of the mesenteriole, one or two being interrupted in the lymph-gland which lies between the layers of this peritoneal fold. They unite to form three or four vessels, which end partly in the lower and partly in the upper lymph-glands of the ileocolic chain. The vessels from the root of the vermiform process and from the cæcum consist of an anterior and a posterior group. The anterior vessels pass in front of the cæcum, and end in the anterior ileocolic lymph-glands and in the upper and lower lymph-glands of the ileocolic chain; the posterior vessels ascend over the back of the cæcum and terminate in the posterior ileocolic lymph-glands and in the lower lymph-glands of the ileocolic chain.

Lymphatic vessels of the colon (fig. 704).—The lymphatic vessels of the ascending and transverse parts of the colon end in the mesenteric lymph-glands, after traversing the right colic and mesocolic lymph-glands. Those of the descending and sigmoid parts of the colon are interrupted by the small lymph-glands on the branches of the left colic and sigmoid arteries, and ultimately end in the pre-aortic lymph-glands around the origin of the inferior mesenteric artery.

Lymphatic vessels of the anus, anal canal, and rectum.—The lymphatics from the *anus* pass forwards and end with those of the integument of the perinæum and scrotum in the superficial inguinal lymph-glands; those from the *anal canal* accompany the middle and inferior hæmorrhoidal arteries, and end in the hypogastric lymph-glands; while those from the *rectum* traverse the pararectal lymph-glands and pass to the lymph-glands in the sigmoid mesocolon; the efferents from the latter terminate in the pre-aortic lymph-glands around the origin of the inferior mesenteric artery.

The *lymphatic vessels of the liver* are divisible into two sets, superficial and deep. The former arise in the subperitoneal areolar tissue over the entire surface of the organ, and may be grouped into: (a) those on the convex surface, (b) those on the inferior surface.

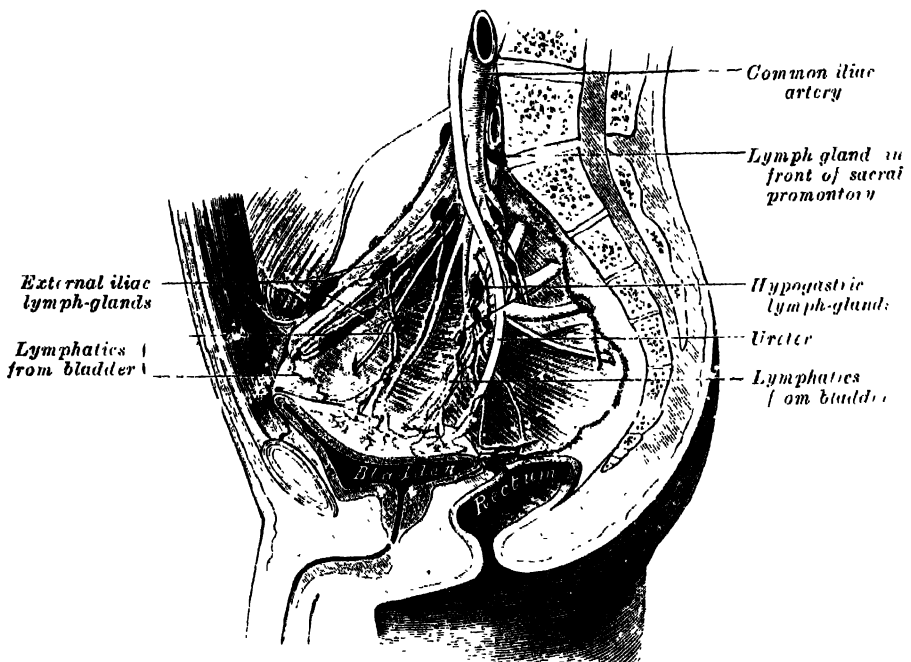
(a) On the *convex surface*.—The vessels from the back part of this surface reach their terminal lymph-glands by three different routes: the vessels of the middle set, five or six in number, pass through the vena-caval foramen in the Diaphragm and end in one or two lymph-glands which are situated around the terminal part of the inferior vena cava; a few vessels from the left side pass backwards towards the oesophageal hiatus, and terminate in the paracardial group of superior gastric lymph-glands; the vessels from the right side, one or two in number, run on the abdominal surface of the Diaphragm, and, after crossing its right crus, end in the pre-aortic lymph-glands which surround the origin of the coeliac artery. From the portions of the right and left lobes adjacent to the falciform ligament, the lymphatic vessels converge to form two trunks, one of which accompanies the inferior vena cava through the Diaphragm, and ends in the lymph-glands around the terminal part of this vessel; the other runs downwards and forwards, and, turning round the anterior sharp margin of the liver, accompanies the upper part of the ligamentum teres, and ends in the upper hepatic lymph-glands. From the anterior surface a few additional vessels turn round the anterior sharp margin to reach the upper hepatic lymph-glands.

(b) On the *inferior surface*.—The vessels from this surface mostly converge to the porta hepatis, and accompany the deep lymphatics emerging from the porta to the hepatic lymph-glands; one or two from the posterior parts of the right and caudate lobes accompany the inferior vena cava through the Diaphragm, and end in the lymph-glands round the terminal part of this vein.

The deep lymphatics converge to ascending and descending trunks. The ascending trunks accompany the hepatic veins and pass through the Diaphragm to end in the lymph-glands round the terminal part of the inferior vena cava. The descending trunks emerge from the porta hepatis, and end in the hepatic lymph-glands.

The *lymphatic vessels of the gall-bladder* pass to the cystic lymph-gland and to the hepatic lymph-glands in the porta hepatis; those of the *common bile-duct* to the hepatic lymph-glands alongside the duct and to the upper pancreaticoduodenal lymph-glands.

FIG. 705.—Lymphatics of the urinary bladder. (Cunéo and Marcille.)



The *lymphatic vessels of the pancreas* follow the course of its blood-vessels. Most of them enter the pancreaticocolic lymph-glands, but some end in the pancreaticoduodenal lymph-glands, and others in the pre-aortic lymph-glands near the origin of the superior mesenteric artery.

(2) The *lymphatic vessels of the spleen and suprarenal glands*.

The *lymphatic vessels of the spleen*, both superficial and deep, accompany the splenic blood-vessels and pass to the pancreaticocolic lymph-glands.

The *lymphatic vessels of the suprarenal glands* usually accompany the suprarenal veins, and end in the lateral aortic lymph-glands; occasionally some of them pierce the crura of the Diaphragm and end in the lymph-glands of the posterior mediastinal cavity.

(3) The *lymphatic vessels of the urinary organs*.

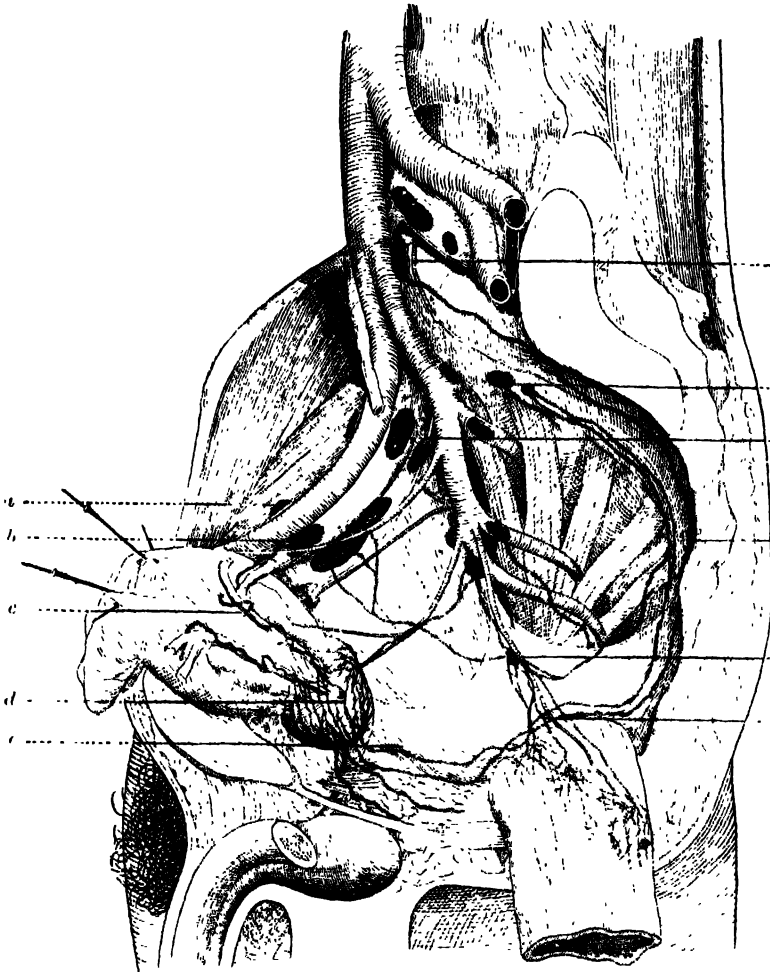
The *lymphatic vessels of the kidney* form three plexuses: one in the substance of the kidney, a second beneath its fibrous capsule, and a third in the perinephric fat; the second and third communicate freely with each other.

The vessels from the plexus in the substance of the kidney converge to form four or five trunks which issue at the hilum. Here they are joined by vessels from the plexus under the capsule, and, following the course of the renal vein,

end in the lateral aortic lymph-glands. The perinephric plexus is drained directly into the upper lateral aortic lymph-glands.

The *lymphatic vessels of the ureter* run in different directions. Those from its upper portion end partly in the efferent vessels from the kidney and partly in the lateral aortic lymph-glands; those from the portion immediately above the brim of the lesser pelvis are drained into the common iliac lymph-glands; while the vessels from the intrapelvic portion of the tube either join the efferents from the bladder, or end in the hypogastric lymph-glands.

FIG. 706.—Lymphatics of the prostate. (Cunéo and Marcille.)



a, b. External iliac lymph-glands. *c.* Vessel draining into external iliac lymph-glands. *d.* Retro-prostatic lymph-glands. *e.* Vessels draining into lymph-gland on sacral promontory. *f.* Lymph-gland in front of sacral promontory. *g.* Lateral sacral lymph-glands. *h.* Middle haemorrhoidal lymphatic vessels. *i.* Middle haemorrhoidal lymphatic vessels.

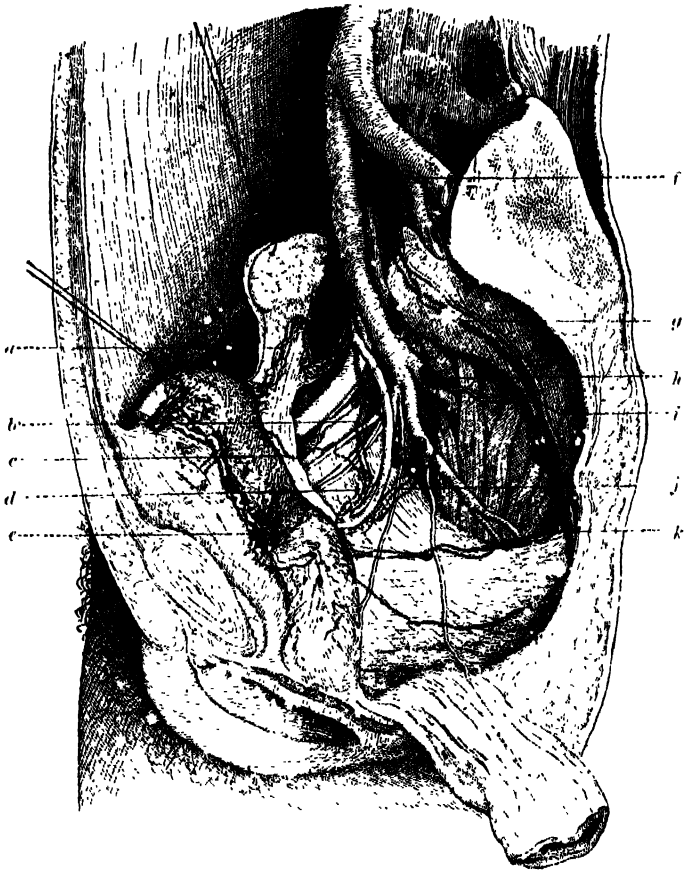
The *lymphatic vessels of the urinary bladder* (fig. 705) begin in two plexuses, an intra- and an extra-muscular, it being generally admitted that the mucous membrane is devoid of lymphatics.* The efferent vessels are arranged in two groups, one from the anterior and another from the posterior surface of the bladder. The vessels from the *anterior* surface pass to the external iliac lymph-glands, but in the course of these vessels minute lymph-glands are situated. These minute lymph-glands are arranged in two groups, an *anterior vesical*, in

* Some authorities maintain that a plexus of lymphatic vessels does exist in the mucous membrane of the bladder (consult *Médecine opératoire des Voies urinaires*, par J. Albarran, Paris, 1909).

front of the bladder, and a *lateral vesical*, in relation to the lateral umbilical ligament. The vessels from the *posterior* surface pass to the hypogastric, external, and common iliac lymph-glands; those draining the upper part of this surface traverse the lateral vesical lymph-glands.

The *lymphatic vessels of the prostate* (fig. 706) terminate chiefly in the hypogastric and sacral lymph-glands, but one trunk from the posterior surface ends in the external iliac lymph-glands, and another from the anterior surface joins the vessels which drain the membranous part of the urethra.

FIG. 707.—Lymphatics of the uterus. (Cunéo and Marcille.)



a. Efferents to lateral aortic lymph-glands. *b, c, d.* Efferents to external iliac lymph-glands. *e.* Network on lateral aspect of cervix uteri. *f.* Lymph-glands in front of sacral promontory. *g.* Efferents to lymph-glands in front of sacral promontory. *h.* Hypogastric lymph-glands. *i.* Lateral sacral lymph-glands. *j.* Vessels draining into hypogastric lymph-glands. *k.* Vessels passing to lateral sacral lymph-glands.

Lymphatic vessels of the urethra.—The lymphatics of the *cavernous* portion of the urethra accompany those of the glans penis, and end with them in the superficial and deep subinguinal and external iliac lymph-glands. Those of the *membranous* and *prostatic* portions, and those of the whole urethra in the female, pass to the hypogastric lymph-glands.

(4) *The lymphatic vessels of the reproductive organs.*

The lymphatic vessels of the testis consist of two sets, superficial and deep, the former commencing on the surface of the tunica vaginalis, the latter in the epididymis and body of the testis. They form from four to eight collecting trunks which ascend with the testicular veins in the spermatic cord and along the front of the Psoas major, and end in the lateral and pre-aortic groups of lumbar lymph-glands.*

* "The Lymphatics of the Testicle," by Jamieson and Dobson, *Lancet*, Feb. 19, 1900.

The *lymphatic vessels of the ductus deferens* pass to the external iliac lymph-glands; those of the *vesiculæ seminales* partly to the hypogastric and partly to the external iliac lymph-glands.

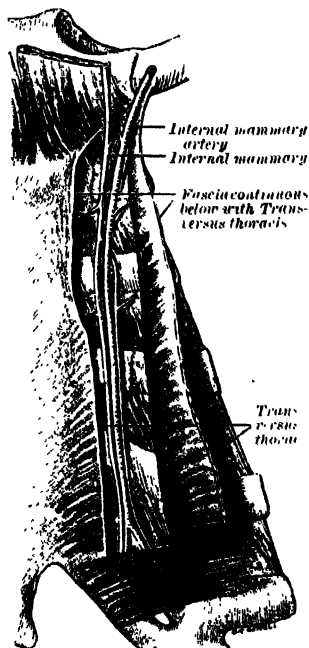
The *lymphatic vessels of the ovary* are similar to those of the testis, and ascend with the ovarian artery to the lateral and pre-aortic lymph-glands.

The *lymphatic vessels of the uterine tube* pass partly with those of the ovary and partly with those of the uterus.

The *lymphatic vessels of the uterus* (fig. 707) consist of two sets, superficial and deep, the former being placed beneath the peritoneum, the latter in the substance of the organ. The lymphatics of the cervix uteri run in three directions: transversely to the external iliac lymph-glands, posterolaterally to the hypogastric lymph-glands, and posteriorly to the common iliac lymph-glands. The majority of the vessels of the body and fundus of the uterus pass lateralwards in the upper parts of the broad ligaments, and ascend alongside the ovarian vessels to the lateral and pre-aortic lymph-glands; a few, however, run to the external iliac lymph-glands, and one or two run along the round ligament of the uterus to the superficial inguinal lymph-glands. In the unimpregnated uterus the lymphatic vessels are very small, but during gestation they are greatly enlarged.

The *lymphatic vessels of the vagina* are carried in three directions: those of the upper part to the external iliac lymph-glands, those of the middle part to the hypogastric lymph-glands, and those of the lower part to the common iliac lymph-glands. On the course of the vessels from the middle and lower parts small lymph-glands are situated. Some lymphatic vessels from the lower part of the vagina join those of the vulva and pass to the superficial inguinal lymph-glands. The lymphatic vessels of the vagina anastomose with those of the cervix uteri, vulva, and rectum, but not with those of the bladder.

FIG. 708.—The right sternal or internal mammary lymph-glands (E. P. Stibbe).



LYMPH-GLANDS OF THE THORAX

The lymph-glands of the thorax may be divided into: 1. parietal and 2. visceral—the former being situated in the thoracic wall, the latter in relation to the viscera.

1. The **parietal lymph-glands** include the sternal, intercostal, and diaphragmatic glands.

(a) The **sternal or internal mammary lymph-glands** are four or five in number on each side, and are placed (fig. 708) at the anterior ends of the intercostal spaces, by the side of the internal mammary artery.* They derive afferents from the mamma, from the deeper structures of the anterior abdominal wall above the level of the umbilicus, from the upper surface of the liver through a small group of lymph-glands which lies behind the xiphoid process, and from the deeper parts of the anterior portion of the thoracic wall. Their efferents usually unite to form a single trunk on either side; this may open directly into the junction of the internal jugular and subclavian veins, or that of the right side may join the right subclavian trunk, and that of the left the thoracic duct.

(b) The **intercostal lymph-glands** lie in the posterior parts of the intercostal spaces and in front of the heads of the ribs. They receive the deep lymphatics from the posterolateral aspect of the chest; some of these vessels are interrupted by small lateral intercostal lymph-glands. The efferents of the lymph-glands in the lower four or five spaces unite to form a trunk, which descends and opens either into the cisterna chyli or into the commencement

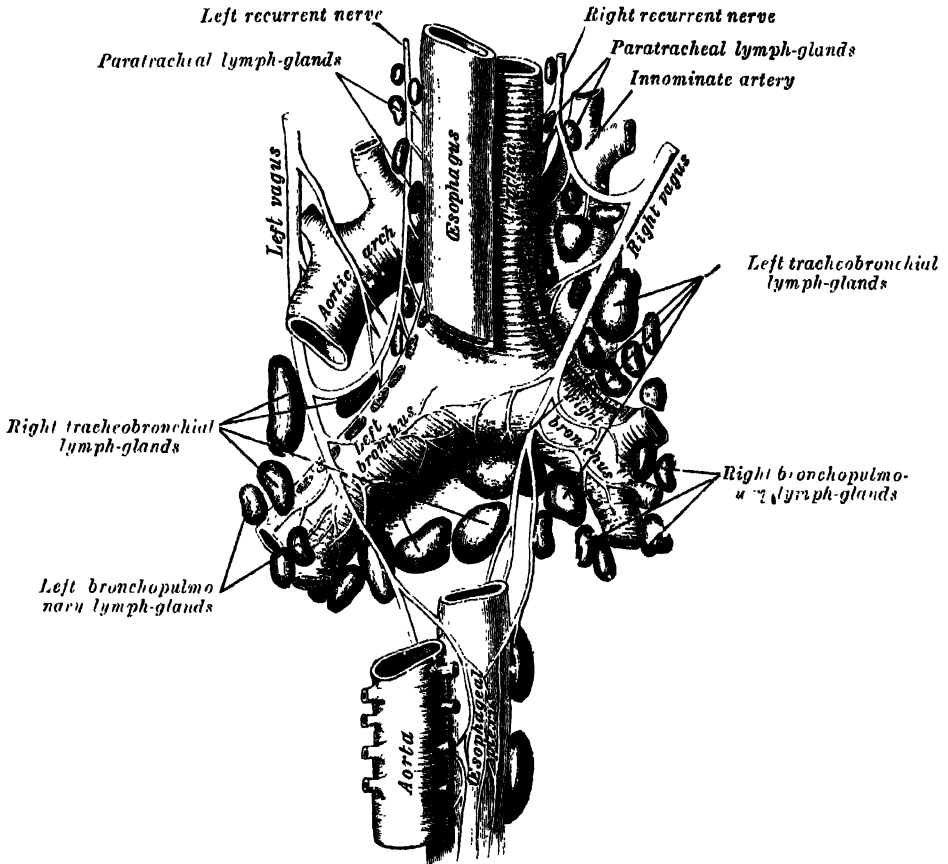
* E. P. Stibbe, *Journal of Anatomy*, vol. 52.

of the thoracic duct. The efferents of the lymph-glands in the upper spaces of the left side end in the thoracic duct; those of the corresponding right-spaces, in the right lymphatic duct.

(c) The **diaphragmatic lymph-glands** lie on the thoracic aspect of the Diaphragm, and consist of three sets, anterior, middle, and posterior.

The *anterior* set comprises (a) two or three small lymph-glands behind the base of the xiphoid process, which receive afferents from the convex surface of the liver, and (b) one or two lymph-glands on either side near the junction

FIG. 709.—The tracheobronchial lymph-glands. (From a figure designed by M. Hallé.)



of the seventh rib with its cartilage, which receive lymphatic vessels from the front part of the Diaphragm. The efferent vessels of the anterior set pass to the sternal lymph-glands.

The *middle* set consists of two or three lymph-glands on either side close to where the phrenic nerves enter the Diaphragm. On the right side some of the lymph-glands of this group lie within the fibrous wall of the pericardium, on the front of the termination of the inferior vena cava. The afferents of this set are derived from the middle part of the Diaphragm, those on the right side also receiving afferents from the convex surface of the liver. Their efferents pass to the posterior mediastinal lymph-glands.

The *posterior* set consists of a few lymph-glands situated on the back of the crura of the Diaphragm, and connected on the one hand with the lumbar lymph-glands, and on the other with the posterior mediastinal lymph-glands.

2. The **visceral lymph-glands** consist of three groups, viz. anterior mediastinal, posterior mediastinal, and tracheobronchial.

The anterior mediastinal lymph-glands are placed in the anterior part of the superior mediastinal cavity, in front of the aortic arch and in relation to the innominate veins and the large arterial trunks which arise from the aortic arch. They receive afferents from the thymus and pericardium, and from the sternal lymph-glands; their efferents unite with those of the tracheobronchial lymph-glands, to form the right and left bronchomediastinal trunks.

The posterior mediastinal lymph-glands lie behind the pericardium in relation to the œsophagus and descending thoracic aorta. Their afferents are derived from the œsophagus, the posterior part of the pericardium, the Diaphragm, and the convex surface of the liver. Their efferents mostly end in the thoracic duct, but some join the tracheobronchial lymph-glands.

The tracheobronchial lymph-glands (fig. 709) form four main groups, and include some of the largest lymph-glands in the body: (a) *tracheal*, on either side of the trachea; (b) *bronchial*, in the angles between the lower part of the trachea and bronchi, and in the angle between the two bronchi; (c) *bronchopulmonary*, in the hilum of each lung; and (d) *pulmonary*, in the lung substance, on the larger branches of the bronchi. The afferents of the tracheobronchial lymph-glands drain the lungs and bronchi, the thoracic part of the trachea, and the heart; some of the efferents of the posterior mediastinal lymph-glands also end in this group. Their efferent vessels ascend upon the trachea and unite with efferents of the internal mammary and anterior mediastinal lymph-glands to form the *right* and *left bronchomediastinal trunks*. The right bronchomediastinal trunk may join the right lymphatic duct, and the left the thoracic duct, but more frequently they open independently of these ducts into the junction of the internal jugular and subclavian veins of their own side.

Applied Anatomy.—In all town-dwellers there are continually being swept into these lymph-glands from the bronchi and alveoli large quantities of the dust and black carbonaceous pigment that are so freely inhaled in cities. At first the lymph-glands are moderately enlarged, firm, inky black and gritty on section; later they enlarge still further, often becoming fibrous from the irritation set up by the minute foreign bodies with which they are crammed, and may break down into a soft slimy mass or may calcify. In tuberculosis of the lungs these lymph-glands are practically always infected; they enlarge, being filled with tuberculous deposits that may soften, or become fibrous, or calcify. Not infrequently an enlarged tuberculous lymph-gland perforates into a bronchus, discharging its contents into the tube. When this happens there is great danger of acute pulmonary tuberculosis, the infecting gland-substance being rapidly spread throughout the bronchial system by the coughing its presence in the air-passages excites.

Tuberculous infection with considerable enlargement of the tracheobronchial glands is common in children. It produces a characteristic patch of impaired resonance on percussion, with increase in the vocal fremitus and resonance and harsh bronchial breath-sounds, over a diamond-shaped area on the back about the region of the third, fourth and fifth dorsal vertebral spines. It is thought, too, that enlargement of these glands produces an irritative dry cough in children, by pressure on the pulmonary nerves in their neighbourhood. Enlargement of these glands can best be diagnosed by use of the x-rays, and, it must be remembered, is not by any means always due to infection with tubercle bacilli. ✓

LYMPHATIC VESSELS OF THE THORAX

The lymphatic vessels of the thorax may be divided into: 1. those of the thoracic wall and 2. those of the thoracic viscera.

1. The *superficial lymphatic vessels of the thoracic wall* ramify beneath the skin and converge to the axillary lymph-glands. Those over the Trapezius and Latissimus dorsi run forwards and unite to form about ten or twelve trunks which end in the subscapular group. Those over the pectoral region, including the vessels from the skin covering the peripheral part of the mamma, run backwards, and those over the Serratus anterior upwards, to the pectoral group. Others near the lateral margin of the sternum pass inwards between the rib cartilages and end in the sternal lymph-glands, while the vessels of opposite sides anastomose across the front of the sternum. A few vessels from the upper part of the pectoral region ascend over the clavicle to the supraclavicular group of cervical lymph-glands.

The *lymphatic vessels of the mamma* originate in a plexus in the interlobular spaces and on the walls of the galactophorous ducts. Those from the central part of the mamma pass to an intricate plexus situated beneath the areola, a plexus which receives also the lymphatics from the skin over the central part of the mamma and those from the areola and nipple. Its efferents are collected into two trunks which pass to the pectoral group of axillary lymph-glands. The vessels which drain the medial part of the mamma pierce the thoracic wall and end in the sternal lymph-glands, while a vessel occasionally emerges from the upper part of the mamma and, piercing the Pectoralis major, terminates in the subclavicular lymph-glands (fig. 694).

The *deep lymphatic vessels of the thoracic wall* consist of :

(a) The lymphatics of the muscles which lie on the ribs : most of these end in the axillary lymph-glands, but some from the Pectoralis major pass to the sternal lymph-glands. (b) The intercostal lymphatic vessels which drain the Intercostales and parietal pleura. Those draining the Intercostales externi run backwards and, after receiving the vessels which accompany the posterior branches of the intercostal arteries, end in the intercostal lymph-glands. Those of the Intercostales interni and parietal pleura consist of a single trunk in each space. These trunks run forwards in the subpleural tissue and the upper six open separately into the sternal lymph-glands or into the vessels which unite them : those of the lower spaces unite to form a single trunk which terminates in the lowest of the sternal lymph-glands. (c) The *lymphatic vessels of the Diaphragm* which form two plexuses, one on its thoracic and another on its abdominal surface ; these plexuses anastomose freely with each other, and are best marked on the parts covered respectively by the pleuræ and peritoneum. That on the thoracic surface communicates with the lymphatics of the costal and mediastinal parts of the pleura, and its efferents consist of three groups : anterior, passing to the lymph-glands which lie near the junction of the seventh rib with its cartilage ; middle, to the lymph-glands on the œsophagus and to those around the termination of the inferior vena cava ; and posterior, to the lymph-glands which surround the aorta at the point where this vessel leaves the thoracic cavity. The plexus on the abdominal surface is composed of fine vessels, and anastomoses with the lymphatics of the liver and, at the periphery of the Diaphragm, with those of the sub-peritoneal tissue. The efferents from the right half of this plexus terminate partly in a group of lymph-glands on the trunk of the corresponding inferior phrenic artery, while others end in the right lateral aortic lymph-glands. Those from the left half of the plexus pass to the pre-aortic and lateral aortic lymph-glands and to the lymph-glands on the terminal portion of the œsophagus.

2. The *lymphatic vessels of the thoracic viscera* comprise those of the heart and pericardium, lungs and pleura, thymus, and œsophagus.

The *lymphatic vessels of the heart* consist of two plexuses : (a) deep, immediately under the endocardium, and (b) superficial, subjacent to the visceral pericardium. The deep plexus opens into the superficial, the efferents of which form left and right collecting trunks. The *left* trunks, two or three in number, ascend in the anterior longitudinal sulcus, receiving, in their course, vessels from both ventricles. On reaching the coronary sulcus they are joined by a large trunk from the diaphragmatic surface of the heart, and then unite to form a single vessel which ascends between the pulmonary artery and the left atrium and ends in one of the tracheobronchial lymph-glands. The *right* trunk receives its afferents from the right atrium and from the right border and diaphragmatic surface of the right ventricle. It ascends in the posterior longitudinal sulcus and then runs forward in the coronary sulcus, and passes up behind the pulmonary artery, to end in one of the tracheobronchial lymph-glands.

The *lymphatic vessels of the lungs* originate in two plexuses, a superficial and a deep. The superficial plexus is placed beneath the pulmonary pleura ; the deep accompanies the branches of the pulmonary vessels and the ramifications of the bronchi. In the case of the larger bronchi the deep plexus consists of two networks—a submucous, beneath the mucous membrane, and a peribronchial, outside the walls of the bronchi. In the smaller bronchi there is but a single plexus, which extends as far as the bronchioles, but fails to reach the alveoli, in the walls of which there are no traces of lymphatic

vessels. The superficial efferents turn round the borders of the lungs and the margins of their fissures, and converge to end in some lymph-glands situated at the hilum; the deep efferents are conducted to the hilum along the pulmonary vessels and bronchi, and end in the tracheobronchial lymph-glands. Little or no anastomosis occurs between the superficial and deep lymphatics of the lungs, except in the region of the hilum.

The *lymphatic vessels of the pleura* consist of two sets—one in the visceral and another in the parietal part of the membrane. Those of the visceral pleura drain into the superficial efferents of the lung, while those of the parietal pleura have three modes of ending, viz.: (a) those of the costal portion join the lymphatics of the Intercostales interni and so reach the sternal lymph-glands; (b) those of the diaphragmatic part are drained by the efferents of the Diaphragm; while (c) those of the mediastinal portion end in the posterior mediastinal lymph-glands.

The *lymphatic vessels of the thymus* end in the anterior mediastinal, tracheobronchial, and sternal lymph-glands.

The *lymphatic vessels of the œsophagus* form a plexus round that tube, and the collecting vessels from the plexus drain into the posterior mediastinal lymph-glands.

NEUROLOGY

THE nervous system is the most complicated and highly organised of the various systems which make up the human body. It is built up of nervous and non-nervous tissues—the former consisting of nerve-cells and nerve-fibres, the latter of neuroglia and blood-vessels, together with certain enveloping membranes.

An outline of the development of the nervous system is given on pp. 85 to 109, and the minute structure of the nervous elements and neuroglia is described on pp. 34 to 40.

The nervous system is usually divided, for descriptive purposes, into the cerebrospinal and sympathetic systems, but this division is an arbitrary one, for the two are intimately connected.

The **cerebrospinal system** is composed of a central and a peripheral part. The *central part* consists of an upper expanded portion, the *encephalon* or *brain*, which is contained within the cranium, and a lower, elongated, cylindrical portion, the *medulla spinalis* or *spinal cord*, which is lodged in the vertebral canal. The two portions are continuous with one another at the level of the upper border of the atlas vertebra, and together constitute the *central nervous system* or *cerebrospinal axis*. The *peripheral part* consists of a series of cerebrospinal nerves which unite the central nervous system to the various parts of the body, and are associated with the functions of the special and general senses, and with the voluntary movements of the body. These nerves are forty-three in number on either side—twelve *cerebral*, attached to the brain, and thirty-one *spinal*, to the medulla spinalis.

The **sympathetic nervous system** transmits impulses which bring about the constriction of the arteries, regulate the movements of the viscera and iris (in association with certain cerebrospinal nerves), stimulate the arrectores pilorum muscles, and excite the secretion of the sudoriferous glands. It comprises two rows of *central ganglia*, one on either side of the middle line in front of the vertebral column, the ganglia of each row being united by vertical strands of nerve-fibres, so as to constitute a pair of knotted cords, named the *sympathetic trunks*. These trunks reach from the base of the skull to the coccyx and are connected to the medulla spinalis and spinal nerves by what are termed white and grey rami communicantes. Nerves issue from the ganglia of the sympathetic trunks and form three great prevertebral plexuses which supply the thoracic, abdominal and pelvic viscera; in relation with the walls of the viscera intricate nerve-plexuses and numerous *peripheral ganglia* are found.

The *white rami communicantes* consist of fine medullated fibres which originate in the cells of the lateral grey column of the medulla spinalis, and pass through the thoracic and the first and second lumbar nerves to the ganglia of the sympathetic trunk. These fibres are named *preganglionic*, and end by forming synapses around the cells of the sympathetic ganglia, while from the cells of these ganglia other fibres, termed *postganglionic*, and which are usually non-medullated, arise. Some of the postganglionic fibres pass directly, or through the prevertebral plexuses, to the involuntary muscles of the vessels and viscera, while others run, in the *grey rami communicantes*, from the ganglia of the sympathetic trunk to all the spinal nerves; by these nerves they are conveyed to the blood-vessels, sudoriferous glands and arrectores pilorum muscles.

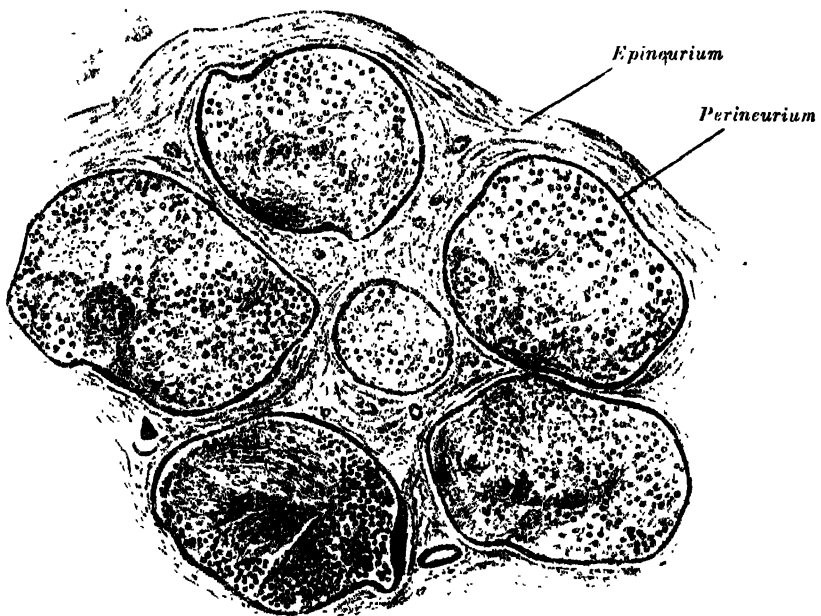
The preganglionic fibres do not all terminate in the ganglia of the sympathetic trunks. Some, as will be described later, run through these ganglia to cell-stations associated with the prevertebral plexuses.

Fine medullated nerve-fibres, homologous with those which go from the medulla spinalis to the sympathetic trunks, issue from (a) certain cerebral nerves (e.g. oculomotor, facial, glossopharyngeal, vagus and accessory), and (b) from the second, third and fourth sacral nerves. These fibres do not join the sympathetic trunks, but terminate in peripheral ganglia, from the cells of which fibres pass to be distributed to secreting glands or involuntary muscle. These nerves, together with those of the sympathetic system, are termed by physiologists *autonomic nerves*. The distinguishing characteristics of all autonomic nerves are: (1) they consist of preganglionic medullated fibres originating in the central nervous system, and postganglionic fibres, usually non-medullated, arising in the ganglia, and (2) they are distributed to structures whose activity is involuntary.

STRUCTURE OF THE PERIPHERAL NERVES AND GANGLIA

The **cerebrospinal nerves** consist of numerous nerve-fibres collected together and enclosed in membranous sheaths (fig. 710). A small bundle of fibres, enclosed

FIG. 710.—Transverse section of a part of a human tibial nerve. $\times 50$.



in a tubular sheath, is called a *funiculus*; if the nerve be small, it may consist of only a single funiculus; but if large, it consists of several funiculi held together and invested by connective tissue; this investment is known as the *epineurium*. Each funiculus is surrounded by a distinct sheath, the *perineurium*; this consists of a fine, smooth, transparent membrane, which may be easily separated, in the form of a tube, from the fibres it encloses; in structure it is made up of connective tissue, which has a lamellar arrangement. The nerve-fibres are held together and supported within the funiculus by delicate connective tissue called the *endoneurium*; it is continuous with septa which pass inwards from the innermost layer of the perineurium, and shows a ground substance in which are imbedded fine bundles of fibrous connective tissue running for the most part longitudinally. The cerebrospinal nerves consist almost exclusively of medullated nerve-fibres, only a very small proportion of non-medullated fibres being present.

The blood-vessels supplying a nerve end in a minute capillary plexus, the vessels composing which pierce the perineurium, and run, for the most part, parallel with the fibres; they are connected together by short, transverse vessels, forming narrow, oblong meshes, similar to the capillary system of muscle. Fine non-medullated nerve-fibres, *vasomotor fibres*, accompany these vessels, and break up into elementary fibrils which form a network around them. Horsley has demonstrated certain medullated fibres running in the epineurium and terminating in small spheroidal tactile corpuscles or end-bulbs of Krause. These nerve-fibres, which Marshall believes to be sensory, and which he has termed *nervi nervorum*, are considered by him to have an important bearing upon certain neuralgic pains.

The nerve-fibres pursue an uninterrupted course from the centre to the periphery. In separating a nerve, however, into its component funiculi, it may be seen that bundles of fibres from one funiculus occasionally join, at a very acute angle, another funiculus proceeding in the same direction; from this, branches are given off, to join again in like manner with other funiculi.

Nerves, in their course, subdivide into branches, and these frequently communicate with branches of a neighbouring nerve. The communications which thus take place form what is called a *plexus*. Sometimes a plexus is formed by the primary branches of the trunks of the nerves—as the cervical, brachial, lumbar, and sacral plexuses—and occasionally by the terminal funiculi, as in the plexuses formed at the periphery of the body. In the formation of a plexus, the component nerves divide, then join, and again subdivide in such a complex manner that the individual funiculi become interlaced most intricately; so that each branch leaving a plexus may contain filaments from all the primary nerves' trunks entering the plexus. In the formation also of smaller plexuses at the periphery of the body there is a free interchange of the funiculi and primitive fibres. In each case, however, the individual fibres remain separate and distinct.

It is probable that, through this interchange of fibres, every branch passing off from a plexus has a more extensive connexion with the medulla spinalis than if it had proceeded to its distribution without forming connexions with other nerves. Consequently the parts supplied by these nerves have more extended relations with the nervous centres; by this means, also, groups of muscles may be associated for combined action.

The **sympathetic nerves** consist largely of non-medullated fibres, collected in funiculi and enclosed in sheaths of connective tissue. There is, however, in these nerves a certain admixture of medullated fibres; thus, the cervical portions of the sympathetic trunk and the splanchnic nerves contain many medullated preganglionic fibres.

The cerebrospinal and sympathetic nerve-fibres convey various impressions. The *sensory* nerves, called also *centripetal* or *afferent* nerves, transmit to the nervous centres impressions made upon the peripheral extremities of the nerves, and in this way the mind, through the medium of the brain, becomes conscious of external objects. The *centrifugal* or *efferent* nerves transmit impressions from the nervous centres to the parts to which the nerves are distributed, these impressions either exciting muscular contraction, or influencing the process of secretion and possibly the processes of nutrition and growth.

Origins of nerves.—The origin of a nerve is in some cases single—that is to say, the whole nerve emerges from the nervous centre by a single root; in other instances the nerve arises by two or more roots which leave different parts of the nerve-centre, sometimes widely apart from each other. The point where the nerve-root or roots emerge from the surface of the nervous centre is named the *superficial* or *apparent* origin, but the fibres of the nerve can be traced for a certain distance into the substance of the nervous centre to some portion of the grey substance, which constitutes the *deep* or *real* origin of the nerve. The centrifugal or efferent nerve-fibres originate in the nerve-cells of the grey substance, the axis-cylinder processes of these cells being prolonged to form the fibres. In the case of the centripetal or afferent nerves the fibres spring from nerve-cells in the organs of special sense (e.g. the retina) or from nerve-cells in the ganglia. Having entered the nerve-centre they branch and send their ultimate twigs among its cells, without, however, uniting with them.

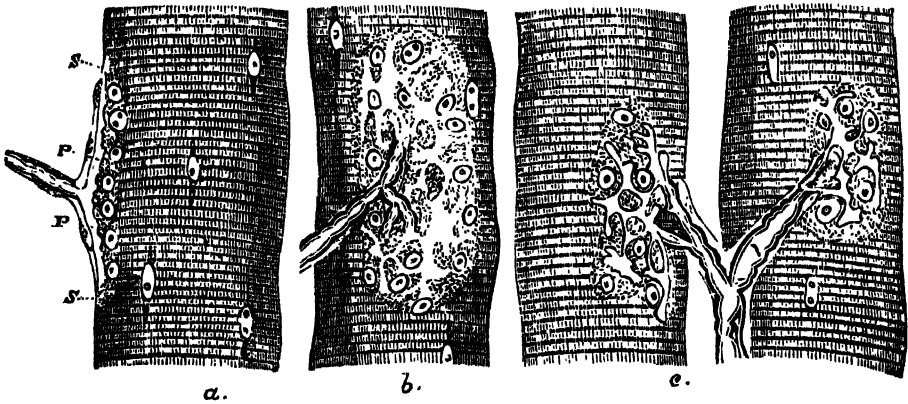
Peripheral terminations of nerves.—Nerve-fibres terminate peripherally in various ways, and these may be conveniently studied in the sensory and motor

nerves respectively. The terminations of the sensory nerves are dealt with in the section on sense-organs.

Motor nerves can be traced to muscular fibres either unstriated or striated. In the *unstriated* or *involuntary muscles* the nerves divide into numerous branches, which communicate and form fine plexuses. At the junctions of the branches small nucleated bodies (ganglion-cells) are situated. From the plexuses minute branches are given off, which divide and break up into the ultimate fibrils of which the nerves are composed. These fibrils course between the involuntary muscle-cells, and, according to Elischer, terminate on the surfaces of the cells, opposite the nuclei, in minute swellings.

In the *striated* or *voluntary muscle* the nerves enter the sheath of the muscle, break up into fibres or bundles of fibres which form plexuses, and gradually divide until, as a rule, a single nerve-fibre enters a single muscular fibre; if the muscular fibre be long, more than one nerve-fibre may enter it. Within the muscular fibre the nerve terminates in a special expansion, called by Kühne, who first accurately described it, a *motor end-plate* (fig. 711). The nerve-fibre, on approaching the

Fig. 711.—Muscular fibres of *Lacerta viridis* with the terminations of nerves.



a. Seen in profile. P P. The nerve end-plates. S S. The base of the plate, consisting of a granular mass with nuclei. b. The same as seen in looking at a perfectly fresh fibre, the nerve-ends being probably still excitable. (The forms of the variously divided plate can hardly be represented in a woodcut by sufficiently delicate and pale contours to reproduce correctly what is seen in Nature.) c. The same as seen two hours after death from poisoning by curare.

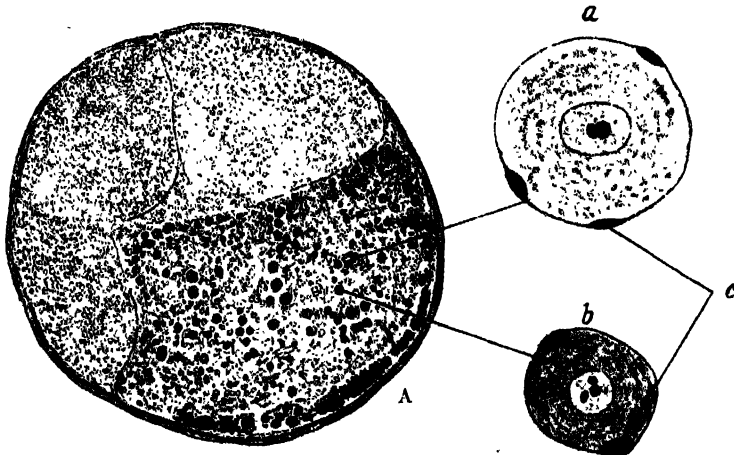
muscular fibre, suddenly loses its medullary sheath, the neurolemma becomes continuous with the sarcolemma of the muscle, and only the axis-cylinder enters the muscular fibre. There it at once spreads out, ramifying like the roots of a tree, immediately beneath the sarcolemma, and becomes imbedded in a layer of granular matter, containing a number of clear, oblong nuclei, the whole constituting an end-plate from which the contractile wave of the muscular fibre is said to start.

Ganglia are small aggregations of nerve-cells. They are found on the posterior roots of the spinal nerves; on the sensory roots of the trigeminal, facial, glossopharyngeal, and vagus nerves, and on the acoustic nerves. They are also found in connexion with the sympathetic nerves. On section they are seen to consist of a reddish-grey substance, traversed by numerous white nerve-fibres; they vary considerably in form and size; the largest are found in the cavity of the abdomen; the smallest, not visible to the naked eye, exist in considerable numbers upon the nerves distributed to the different viscera. Each ganglion is invested by a smooth and firm, closely adhering, membranous envelope, consisting of dense areolar tissue; this sheath is continuous with the perineurium of the nerves, and sends numerous processes into the interior of the ganglion.

In structure all ganglia are essentially similar, consisting of the same structural elements—viz. nerve-cells and nerve-fibres. Each nerve-cell has a nucleated sheath which is continuous with the neurolemma of the nerve-fibre with which the cell is connected. The nerve-cells in the ganglia of the spinal nerves (fig. 712) are pyriform in shape, and each has a single process which acquires a medullary sheath soon after leaving the cell. The process runs towards the centre of the ganglion, and divides in a T-shaped manner, one limb of the cross-bar entering the medulla

spinalis, the other limb passing outwards to the periphery. In the sympathetic ganglia (fig. 713) the nerve-cells are multipolar and each has one axis-cylinder process and several dendrons; the axon emerges from the ganglion as a non-medullated nerve-fibre. The spinal and sympathetic ganglia differ somewhat

FIG. 712.—Transverse section of a spinal ganglion of a rabbit.

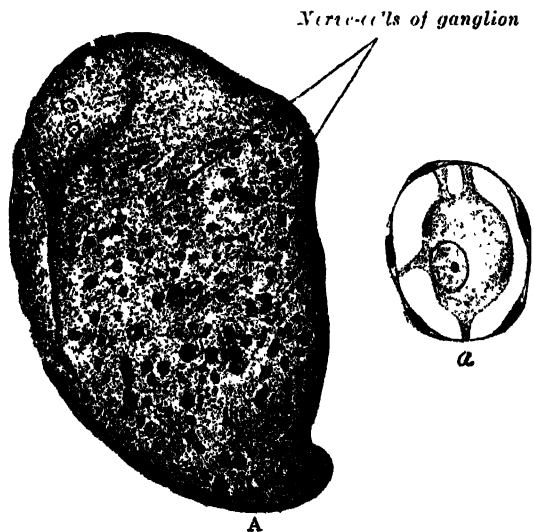


A. Ganglion $\times 20$. a. Large clear nerve-cell; b. small deeply staining nerve-cell; c. nuclei of capsule $\times 350$. The lines in the centre point to the corresponding cells in the ganglion.

in the size and disposition of the cells and in the number of nerve-fibres entering and leaving them. In the spinal ganglia (fig. 712) the nerve-cells are much larger and for the most part collected in groups near the periphery, while the fibres, which are mostly medullated, traverse the central portion of the ganglion; whereas in the sympathetic ganglia (fig. 713) the cells are smaller and distributed in irregular groups throughout the whole ganglion; the fibres also are irregularly scattered; some of those entering are medullated, while many leaving the ganglion are non-medullated.

Neuron theory.—The nerve-cell and its processes collectively constitute what is termed a *neuron*, and Waldeyer formulated the theory that the nervous system is built up of numerous neurons, 'anatomically and genetically independent of one another.' According to this *neuron theory* the processes of one neuron only come into contact, and are never in direct continuity, with those of other neurons; impulses being transmitted from one nerve-cell to another through the points of contact. This theory is based on the following facts, viz.: (1) embryonic nerve-cells or neuroblasts are entirely distinct from one another; (2) when nervous tissues are stained by the Golgi method no continuity is seen even between neighbouring neurons; and (3) when degenerative changes occur in nervous tissue, either as the result of disease or experiment, they never spread from one neuron to another, but are limited to the individual neurons, or groups of neurons, primarily affected. It must, however, be added that the validity of the neuron theory has been called in question by certain eminent histologists, who maintain that by the employment of more delicate histological methods, minute fibrils can be followed from one nerve-cell into another.

FIG. 713.—Transverse section of a sympathetic ganglion of a cat.



A. Ganglion $\times 30$. a. A nerve-cell $\times 350$

THE MEDULLA SPINALIS OR SPINAL CORD

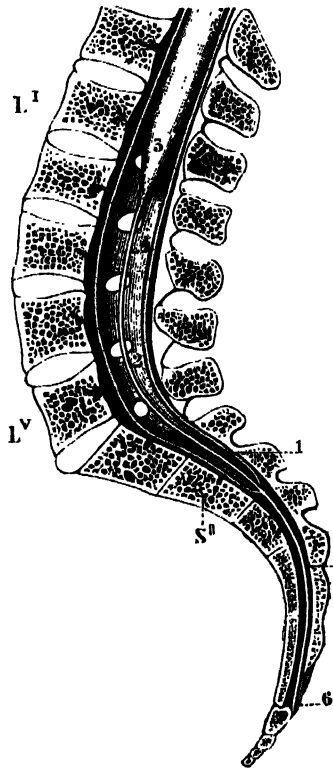
The **medulla spinalis** or **spinal cord** is the elongated, nearly cylindrical, part of the central nervous system which occupies the upper two-thirds of the vertebral canal. Its average length in the male is 45 cm.; its weight is about 30 gms. It extends from the level of the upper border of the atlas vertebra to that of the lower border of the first, or upper border of the second, lumbar vertebra. Above, it is continuous with the brain; below, it ends in the *conus medullaris*, from the apex of which a delicate non-nervous filament, the *filum terminale*, descends as far as the first segment of the coccyx (fig. 714).

The position of the medulla spinalis varies with the movements of the vertebral column, its lower extremity being raised slightly when the column is flexed. It also varies at different periods of life: up to the third month of fetal life the medulla spinalis is as long as the vertebral canal, but from this stage onwards the vertebral column grows in length more rapidly than the medulla spinalis, so that by the end of the fifth month the lower end of the medulla spinalis is at the base of the sacrum, and at birth about the third lumbar vertebra. In the early embryo the nerve-roots pass transversely outwards to their respective intervertebral foramina, but owing to the relative inequality in the rates of growth of the medulla spinalis and vertebral column, the nerve-roots become more and more oblique in direction, so that in the adult the lumbar and sacral nerves descend almost vertically to reach their foramina. From the appearance these nerves present at their attachment to the medulla spinalis and from their great length they are collectively termed the *cauda equina* (fig. 716).

The medulla spinalis is ensheathed by three protective membranes which are separated from each other by concentric spaces. The membranes are named from without inwards the *dura mater*, the *arachnoid*, and the *pia mater* (fig. 715). The *dura mater*, a strong, fibrous membrane, forms a wide, tubular sheath which extends below the termination of the medulla spinalis and ends in a pointed cul-de-sac at the level of the lower border of the second sacral vertebra. The *dura mater* is separated from the wall of the vertebral canal by the *epidural cavity*, which contains a quantity of areolar tissue, fat, and a plexus of veins; between the *dura mater* and the subjacent *arachnoid* is the *subdural cavity*, a capillary interval containing a small quantity of fluid, probably of the nature of lymph. The *arachnoid* is a thin, transparent sheath, and is separated from the *pia mater* by the *subarachnoid cavity*, filled with cerebrospinal fluid. The *pia mater* closely invests the medulla spinalis and sends delicate septa into its substance; from each lateral surface of the *pia mater* a fibrous band, named the *ligamentum denticulatum*, projects into the subarachnoid space, and is attached by a series of pointed processes to the inner surface of the *dura mater*.

Thirty-one pairs of spinal nerves spring from the medulla spinalis, each

FIG. 714.—Sagittal section of the vertebral canal to show the lower end of the medulla spinalis and the *filum terminale*. (Testut.)

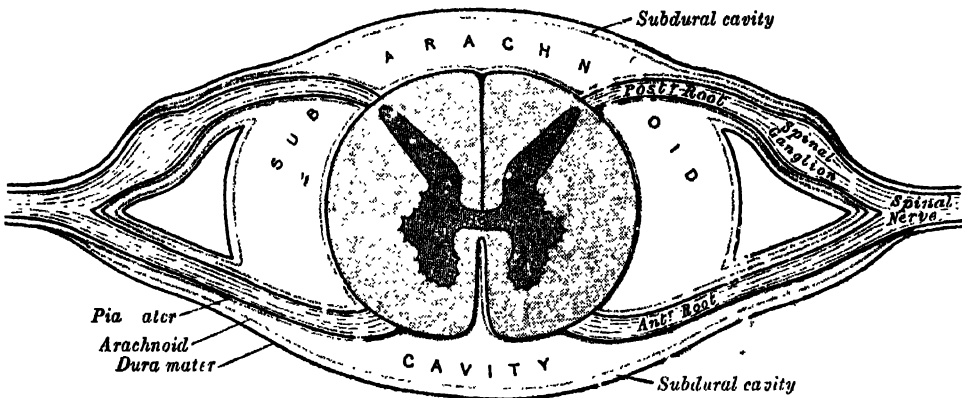


L1, L5. First and fifth lumbar vertebrae. S2. Second sacral vertebra. 1. Dura mater. 2. Lower part of tube of dura mater. 3. Lower extremity of medulla spinalis. 4. Intra-dural, and 5. Extra-dural portions of filum terminale. 6. Attachment of filum terminale to first segment of coccyx.

nerve having an anterior and a posterior root, the latter being distinguished by the presence of an oval swelling, the *spinal ganglion*, which contains numerous nerve-cells. Each root consists of several bundles of nerve-fibres, and at its attachment extends for some distance along the side of the medulla spinalis. The pairs of spinal nerves are grouped as follows: cervical 8, thoracic 12, lumbar 5, sacral 5, coccygeal 1, and, for convenience of description, the medulla spinalis is divided into cervical, thoracic, lumbar, and sacral regions, corresponding with the attachments of the different groups of nerves.

Although no trace of transverse segmentation is visible on the surface of the medulla spinalis, it is convenient to regard it as being built up of a series of superimposed *spinal segments* or *neuromeres*, each of which has a length equivalent to the extent of attachment of a pair of spinal nerves. Since the extent of attachment of the successive pairs of nerves varies in different parts, it follows that the spinal segments are of varying lengths; thus, in the cervical region they average 13 mm., in the mid-thoracic region 26 mm., while in the lumbar and sacral regions they diminish rapidly from 15 mm. at the level of the first pair of lumbar nerves to 4 mm. opposite the attachments of the lower sacral nerves.

FIG. 715.—Diagrammatic transverse section of the medulla spinalis and its membranes.



The *filum terminale* (figs. 714, 716) is a delicate filament, about 20 cm. in length, prolonged downwards from the apex of the conus medullaris. Its upper part, or *filum terminale internum*, about 15 cm. long, is contained within the tubular sheath of dura mater and reaches as far as the lower border of the second sacral vertebra. It is surrounded by the nerves forming the cauda equina, but can be readily distinguished from them by its bluish-white colour. Its lower part, or *filum terminale externum*, is closely invested by, and adherent to, the dura mater; it descends from the apex of the tubular sheath of dura mater and is attached to the back of the first segment of the coccyx. The *filum terminale* consists mainly of fibrous tissue, continuous above with that of the pia mater, but adhering to its outer surface are a few strands of nerve-fibres which probably represent rudimentary second and third coccygeal nerves; further, the central canal of the medulla spinalis is continued downwards into it for 5 or 6 cm.

Enlargements.—The medulla spinalis is not quite cylindrical, being slightly flattened from before backwards; it also presents two swellings or enlargements, an upper or cervical, and a lower or lumbar (fig. 717).

The *cervical enlargement* is the more pronounced, and corresponds with the attachments of the large nerves of the upper limbs. It extends from about the third cervical to the second thoracic vertebra, its maximum circumference (about 38 mm.) being at the level of the attachment of the sixth pair of cervical nerves.

To the *lumbar enlargement* are attached the nerves of the lower limbs. It begins at the level of the ninth thoracic vertebra, and reaches its maximum circumference, of about 33 mm., opposite the last thoracic vertebra, below which it tapers rapidly into the conus medullaris.

Fissure and sulci (fig. 718).—An anterior median fissure and a posterior median sulcus incompletely divide the medulla spinalis into two symmetrical parts, which are joined across the middle line by a commissural band of nervous matter.

The *anterior median fissure* has an average depth of about 3 mm., but is deepest in the lower part of the medulla spinalis. It contains a double fold of pia mater, and its floor is formed by a transverse band of white substance, the *anterior white commissure*, which is perforated by blood-vessels on their way to or from the central part of the medulla spinalis.

FIG. 716.—The cauda equina and filum terminale seen from behind. The dura mater has been opened and spread out, and the arachnoid has been removed.

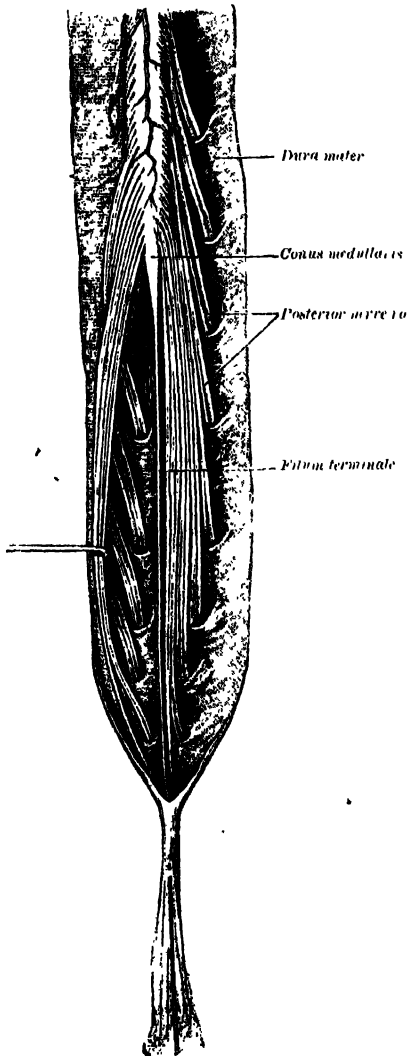
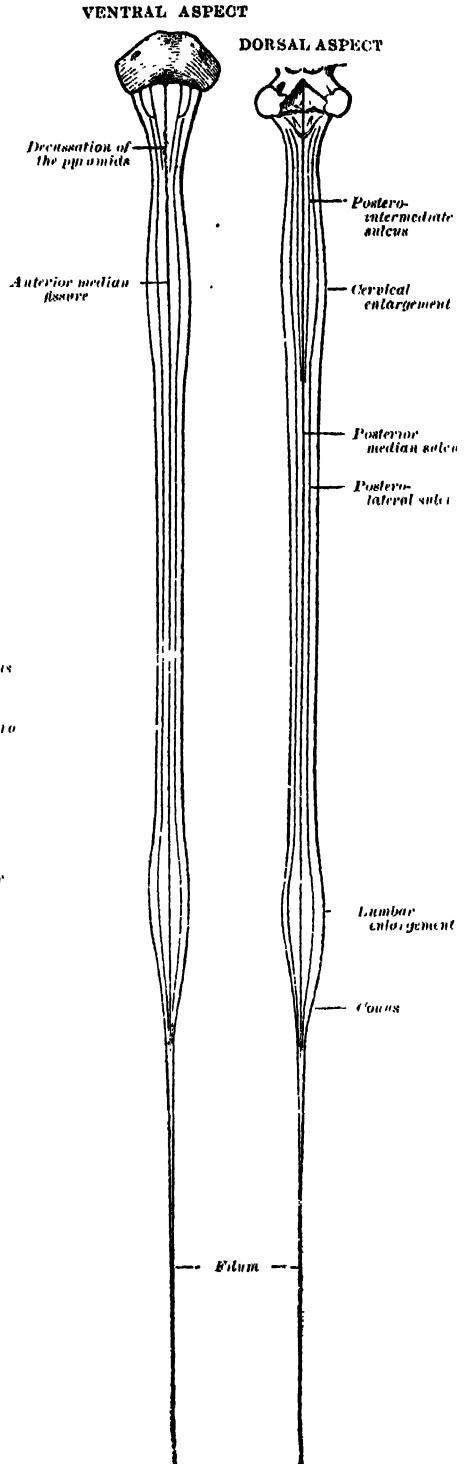


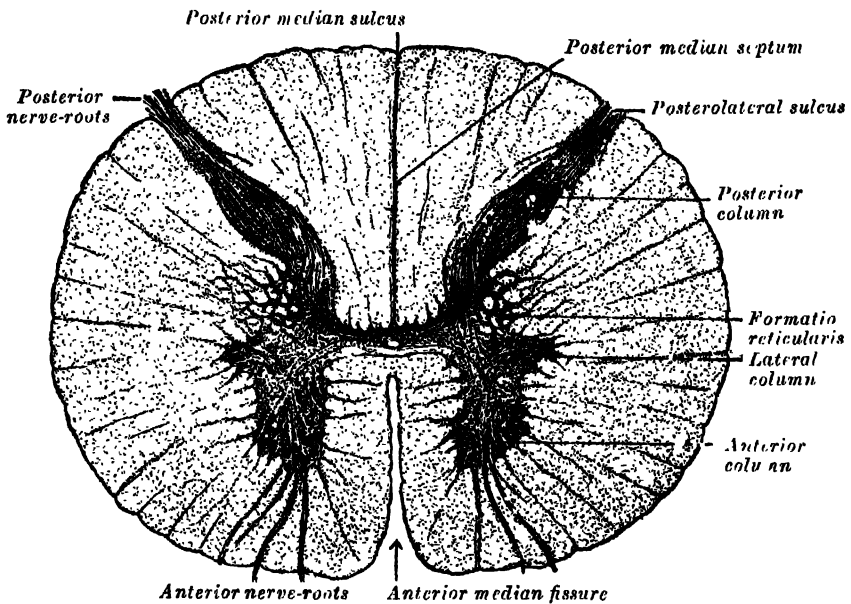
FIG. 717.—Diagrams of the medulla spinalis.



The *posterior median sulcus* is very shallow; from it a septum of neuroglia reaches rather more than half-way into the substance of the medulla spinalis; this septum varies in depth from 4 to 6 mm., but diminishes considerably in the lower part of the medulla spinalis.

On either side of the posterior median sulcus, and at a short distance from it, the posterior nerve-roots are attached along a vertical furrow named the *posterolateral sulcus*. The portion of the medulla spinalis which lies between this and the posterior median septum is named the *posterior funiculus*. In the cervical and upper thoracic regions the surface of this funiculus presents a longitudinal furrow, the *postero-intermediate sulcus*: this marks the position of a septum which extends into the posterior funiculus and subdivides it into two fasciculi—a medial, named the *fasciculus gracilis* (tract of Coll); and a lateral, the *fasciculus cuneatus* (tract of Burdach) (fig. 724).

FIG. 718.—Transverse section of the medulla spinalis in the mid-thoracic region.



The portion of the medulla spinalis between the posterolateral sulcus and the anterior median fissure is termed the *anterolateral region*. The anterior nerve-roots, unlike the posterior, are not attached in linear series, and their positions of exit are not marked by a sulcus; they arise by separate bundles which spring from the anterior column of grey substance and, passing forward through the white substance, emerge over an area of some width. The most lateral of these bundles is generally taken as a dividing line which separates the anterolateral region into two parts, viz. an *anterior funiculus*, between the anterior median fissure and the most lateral of the anterior nerve-roots; and a *lateral funiculus*, between the exit of these roots and the posterolateral sulcus. In the upper part of the cervical region a series of nerve-roots passes outwards through the lateral funiculus of the medulla spinalis; these unite to form the spinal portion of the accessory nerve, which runs upwards and enters the cranial cavity through the foramen magnum.

INTERNAL STRUCTURE OF THE MEDULLA SPINALIS

The medulla spinalis is composed of grey and white nervous substance, the former being enclosed within the latter (fig. 718).

Grey substance.—The grey substance consists of two symmetrical portions, one in either half of the medulla spinalis: these are joined across the middle

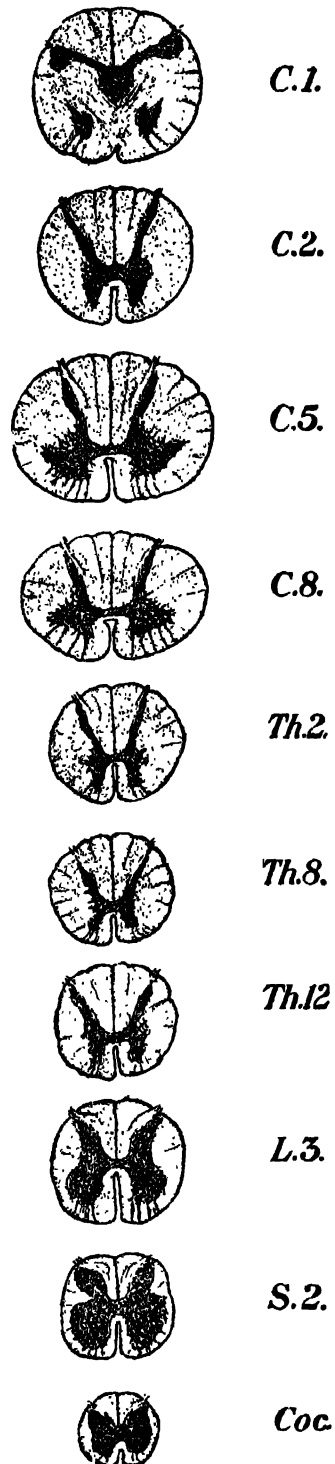
line by a transverse commissure of grey substance which is traversed by a small canal, the *central canal*, just visible to the naked eye. In a transverse section each half of the grey substance is shaped like a comma or crescent with its concavity directed laterally; and these, together with the intervening grey commissure, present the appearance of the letter H. An imaginary coronal plane through the central canal serves to divide each crescent into an anterior and a posterior column.

The **anterior column** (anterior cornu) is directed forwards; it is broad, and round or quadrangular in shape. Its posterior part is termed the *base*, and its anterior part the *head*, but these are not separated from each other by any well-defined constriction. Between the head of the anterior column and the surface of the medulla spinalis is a layer of white substance which is traversed by the bundles of the anterior nerve-roots. In the thoracic region, the posterior part of the anterior column projects lateralwards as a triangular field, named the **lateral column** (lateral cornu).

The **posterior column** (posterior cornu) is long and slender, and is directed backwards and lateralwards; it reaches almost as far as the posterolateral sulcus, from which it is separated by a thin layer of white substance, the *tract of Lissauer*. It consists of a *base*, directly continuous with the base of the anterior horn, and a *neck* or slightly constricted portion, which is succeeded by an oval or fusiform area, termed the *head*, of which the *apex* approaches the posterolateral sulcus. The apex is capped by a mass of translucent, gelatinous neuroglia, termed the *substantia gelatinosa* of *Rolando*, which contains both neuroglia-cells and small nerve-cells and is V-shaped or crescentic on transverse section. Between the anterior and posterior columns the grey substance extends as a series of processes into the lateral funiculus, and forms a network called the *formatio reticularis*.

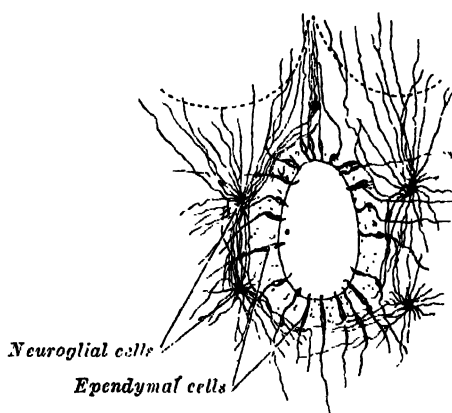
The quantity of grey substance and the form it presents on transverse section vary at different levels. In the thoracic region the grey substance is small in amount, not only absolutely but relatively to the surrounding white substance. In the cervical and lumbar enlargements it is greatly increased; in the latter, and especially in the *conus medullaris*, its proportion to the white substance is greatest (fig. 719). In the cervical region the posterior column of grey substance is comparatively narrow, while its anterior is broad and expanded; in the thoracic region, both columns are narrow, and the lateral column is evident; in the lumbar enlargement the anterior and posterior columns are both expanded; while in the *conus medullaris* the grey substance assumes the form of two oval masses, one in either half of the cord, connected together by a broad grey commissure.

FIG. 719.—Transverse sections of the medulla spinalis at different levels.



The central canal traverses the entire length of the medulla spinalis. The grey substance in front of the canal is named the *anterior grey commissure*; that behind it, the *posterior grey commissure*. The anterior grey commissure is thin, and in contact anteriorly with the anterior white commissure: it contains a pair of longitudinal veins, one on either side of the middle line. The posterior grey commissure reaches from the central canal to the posterior median septum; is thinnest in the thoracic region, and thickest in the conus medullaris. The central canal is continued upwards through the lower part of the medulla oblongata and opens into the fourth ventricle of the brain; below it reaches for a short distance (5-6 cm.) into the filum terminale. In the lower part of the conus medullaris it exhibits a fusiform dilatation, the *terminal ventricle*; this has a vertical measurement of from 8 to 10 mm., is triangular on cross section with its base directed forwards, and tends to undergo obliteration after the age of forty years.

FIG. 720.—Section of the central canal of the medulla spinalis, showing the ependymal and neuroglial cells. (Lenhossék.)



Throughout the cervical and thoracic regions the central canal is situated in the anterior third of the medulla spinalis: in the lumbar enlargement it is near the middle, and in the conus medullaris it approaches the posterior surface. It is filled with cerebrospinal fluid, and lined by ciliated, columnar epithelium, which is encircled by a band of gelatinous substance, the *substantia gelatinosa centralis*. This gelatinous substance consists mainly of neuroglia, but contains a few nerve-cells and nerve-fibres; it is traversed by processes from the deep ends of the cells which line the central canal (fig. 720).

Structure of the grey substance.—The grey substance consists of nerve-cells, nerve-fibres and neuroglia. Throughout the greater part of it the neuroglia has the appearance of a sponge-like network, but around the central canal and on the apices of the posterior columns it consists of the gelatinous substance already referred to. The nerve-cells are multipolar, and vary greatly in size and shape. They consist of: (1) Motor cells of large size, which are situated in the anterior column, and are especially numerous in the cervical and lumbar enlargements; the axons of most of these cells pass out to form the anterior nerve-roots, but before leaving the white substance they frequently give off collaterals, which re-enter and ramify in the grey substance.* (2) Cells of small or medium size, whose axons pass into the white matter, where some pursue an ascending, and others a descending course, but most of them divide in a T-shaped manner into descending and ascending processes. They give off collaterals which enter and ramify in the grey substance, and the terminations of the axons behave in a similar manner. The lengths of these axons vary greatly: some are short and pass only between adjoining spinal segments,

* Lenhossék and Cajal found that in the embryo of the chick the axons of a few of these nerve-cells passed backwards through the posterior column, and emerged as the *motor fibres* of the *posterior nerve-roots*. These fibres are said to control the peristaltic movements of the intestine. Their presence in man has not yet been determined.

while others are longer and connect more distant segments. These cells and their processes constitute a series of *association* or *intersegmental neurons* (fig. 721), which link together the different parts of the medulla spinalis. The axons of most of these cells are confined to that side of the medulla spinalis in which the nerve-cells are situated, but some cross to the opposite side through the anterior commissure, and are termed *crossed commissural fibres*. Some of the latter end directly in the grey substance, while others enter the white substance, and ascend or descend in it for varying distances, before finally terminating in the grey substance. (3) Cells of type II. of Golgi, limited to the posterior column, are found in the substantia gelatinosa of Rolando; their axons are short and confined to the grey substance, in which they break up into numerous fine filaments. Most of the nerve-cells are arranged in longitudinal columns, and appear as groups on transverse section (figs. 722, 723).

Nerve-cells in the anterior column.—The nerve-cells in the anterior column are arranged in columns of varying length. The longest occupies the medial part of the anterior column and is named the *anteromedial* column: it is absent only in the fifth lumbar, the first sacral and the upper part of the second sacral segments (Bruce*). Behind it, is a *posteromedial* column of small cells, which extends from the second thoracic to the first lumbar segment and is also present in the first, sixth, and seventh cervical segments.

In the cervical and lumbar enlargements, where the anterior column is expanded in a lateral direction, the following additional columns are present, viz.—(a) *anterolateral*, in the fourth, fifth, and sixth cervical, second thoracic, lower four lumbar and upper two sacral segments; (b) *posterolateral*, in the lower five cervical, lower four lumbar, and upper three sacral segments; (c) *post-posterolateral*, in the last cervical, first thoracic, and upper three sacral segments; and (d) *central*, in the lower four lumbar and upper two sacral segments. Throughout the base of the anterior column are solitary cells, the axons of some of which form crossed commissural fibres, while others constitute the motor fibres of the posterior nerve-root (p. 750, footnote).

Nerve-cells in the lateral column.—These form a column which is best marked in the thoracic region; it extends from the middle of the eighth cervical segment to the lower part of the second lumbar or upper part of the third lumbar segment,† but can be traced throughout the entire length of the medulla spinalis in the form of groups of small cells situated in the anterior part of the *formatio reticularis*. The cells of this column are fusiform or star-shaped, and of a medium size: the axons of many of them pass into the anterior nerve-roots, and are conveyed to the sympathetic trunks through the white rami communicantes; while the axons of others pass into the anterior and lateral* funiculi, where they become longitudinal.

Nerve-cells in the posterior column.—1. The *dorsal nucleus* (column of Clarke) occupies the medial part of the base of the posterior column, and appears on transverse section as a well-defined oval area. It begins below at

FIG. 721.—Cells of medulla spinalis. (Poirier.)

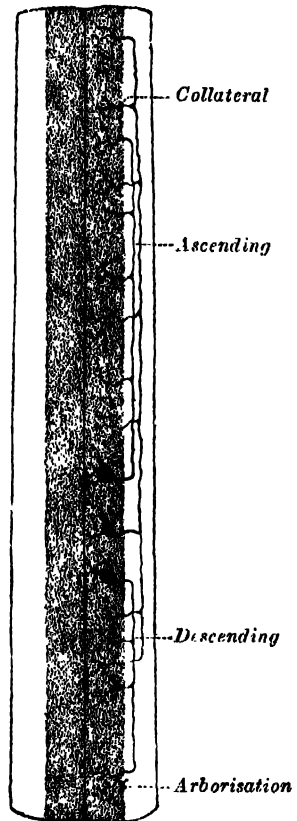


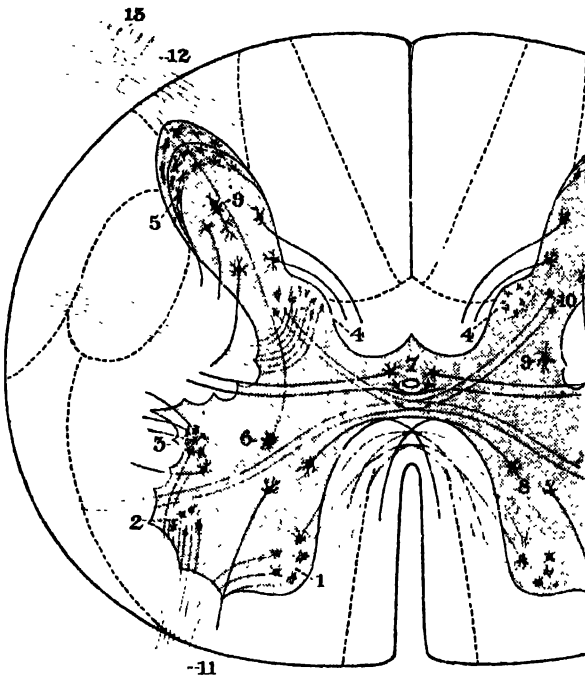
Diagram showing in longitudinal section the intersegmental neurons of the medulla spinalis. The grey and white parts correspond respectively to the grey and white substance of the medulla spinalis.

* *Topographical Atlas of the Spinal Cord*. 1901.

† Bruce and Pirie, *British Medical Journal*, Nov. 17, 1906.

the level of the second or third lumbar nerve, and reaches its maximum size opposite the twelfth thoracic nerve. It diminishes in size above the level of the ninth thoracic nerve, and ends opposite the last cervical or first thoracic nerve. It is represented, however, in the other regions by scattered cells, which are aggregated to form a *cervical nucleus* opposite the third cervical nerve, and a *sacral nucleus* in the middle and lower part of the sacral region. Its cells are of medium size, and oval or pyriform in shape; many of their axons pass into the peripheral part of the lateral funiculus of the same side, and there ascend, under the name of the *direct cerebellar tract*; others cross to the opposite side and ascend as the *superficial anterolateral fasciculus*.

FIG. 722.—Mode of distribution of the nerve-cells in the grey substance. (Schematic.) (Testut.)



1, 2. Medial and lateral groups of nerve-cells in anterior column. 3. Nerve-cells in lateral column. 4, 4. Dorsal nucleus. 5. Group of nerve-cells in substantia gelatinosa of Rolando. 6. Nerve-cell of anterior column, the axon of which is passing into the posterior nerve-root. 7. Cells of substantia gelatinosa centralis. 8. Solitary cell. 9. Cells of Golgi. 10. Cells of origin of the superficial anterolateral fasciculus. 11. Anterior root. 12. Posterior root. 13. Spinal ganglion.

2. *Nerve-cells in the substantia gelatinosa of Rolando.*—These are arranged in three zones: a posterior or marginal, of large triangular or fusiform cells; an intermediate, of small fusiform cells; and an anterior, of star-shaped cells. The axons of these cells pass into the lateral and posterior funiculi, and there assume a vertical course. In the anterior zone some Golgi cells are found, the short axons of which ramify in the grey substance.

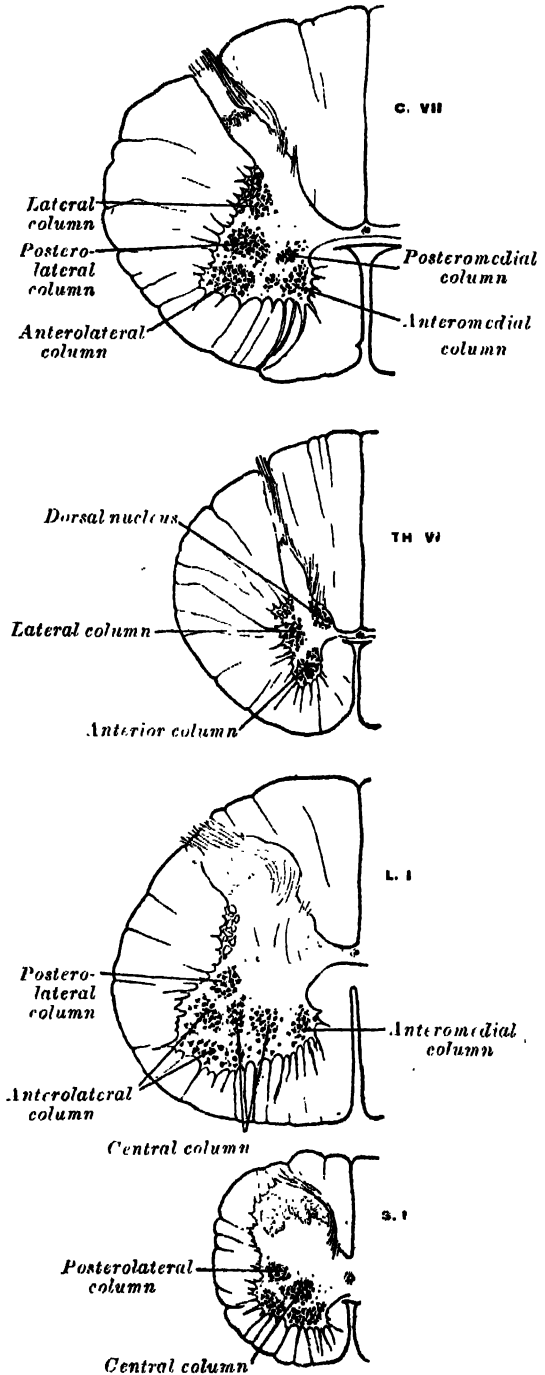
3. *Solitary cells of varying form and size* are scattered throughout the posterior column. Some of these are grouped to form the *posterior basal column* in the base of the posterior column, lateral to the dorsal nucleus. The posterior basal column is well-marked in the gorilla (Waldeyer), but ill-defined in man. The axons of its cells pass partly to the posterior and lateral funiculi of the same side, and partly through the anterior white commissure to the lateral funiculus of the opposite side. Before leaving the grey substance, a considerable number run longitudinally for a varying distance in the head of the posterior column, forming what is termed the *longitudinal fasciculus* of the posterior column.

A few star-shaped or fusiform nerve-cells of varying size are found in the substantia gelatinosa centralis. Their axons pass into the lateral funiculus of the same, or opposite, side.

The nerve-fibres in the grey substance form a dense interlacement among the nerve-cells. This interlacement is formed partly of axons which pass from the cells in the grey substance to enter the white funiculi or nerve-roots; partly of the axons of Golgi's cells which ramify only in the grey substance; and partly of collaterals from the nerve fibres in the white funiculi, which, as already stated, enter the grey substance and ramify within it.

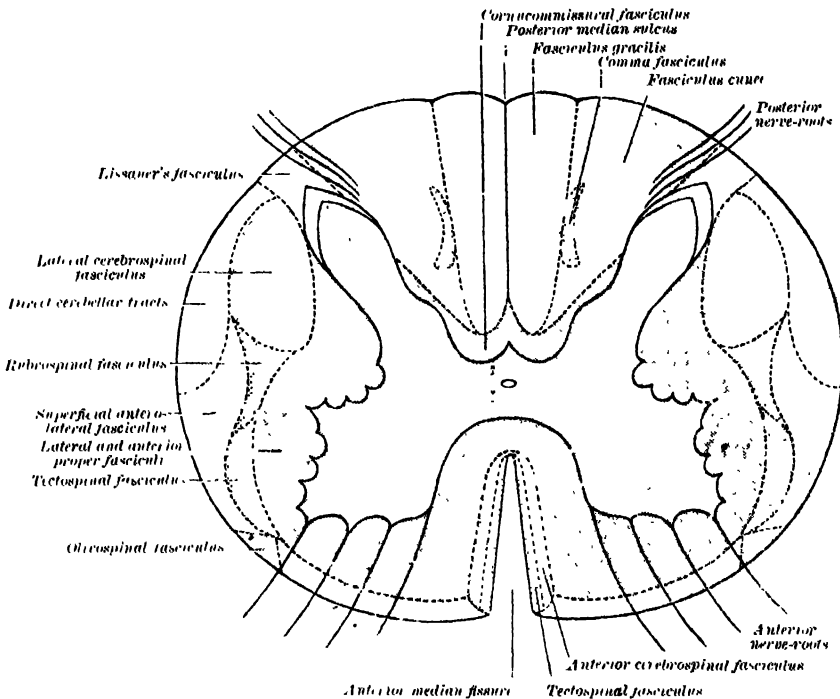
White substance.—The white substance of the medulla spinalis consists of medullated nerve-fibres imbedded in a sponge-like network of neuroglia, and arranged in three funiculi: anterior, lateral, and posterior. The anterior funiculus lies between the anterior median fissure and the most lateral of the anterior nerve-roots; the lateral funiculus between these nerve-roots and the posterolateral sulcus; and the posterior funiculus between the posterolateral sulcus and the posterior median septum (fig. 724). The fibres vary in thickness; the thinnest are found in the fasciculus gracilis, the tract of Lissauer, and the central part of the lateral funiculus; the thickest are situated in the anterior funiculus, and in the peripheral part of the lateral funiculus. Some of the nerve-fibres assume a more or less transverse direction, as for example those which cross the middle line in the anterior white commissure, but the majority pursue a longitudinal course and are divisible into (1) those connecting the medulla spinalis with the brain, and conveying impulses to or from the latter, and (2) those which are confined to the medulla spinalis and link together its different segments (i.e. intersegmental or association fibres).

FIG. 723.—Transverse sections of the medulla spinalis at different levels to show the arrangement of the principal cell-columns.



Nerve-fasciculi.—The longitudinal fibres are grouped into more or less definite bundles or fasciculi. These are not recognisable from each other in the natural state, and their existence has been determined by the following methods: (1) A. Waller discovered that if a bundle of nerve-fibres be cut, the portions of the fibres which are separated from their cells rapidly degenerate and become atrophied, while the cells and the parts of the fibres connected with them undergo little alteration.* This is known as *Wallerian degeneration*. Similarly, if a group of nerve-cells be destroyed, the fibres arising from them undergo degeneration. Thus, if the motor cells of the cerebral cortex be destroyed, or if the fibres arising from these cells be severed, a *descending* degeneration from the seat of injury takes place in the fibres. In the same

FIG. 724.—Diagram of the principal fasciculi of white substance in the medulla spinalis.



manner, if a spinal ganglion be destroyed, or the fibres which pass from it into the medulla spinalis be cut, an *ascending* degeneration occurs in these fibres above the lesion. (2) By tracing the development of the nervous system, it has been observed that at first the nerve-fibres are naked axis-cylinders, and that all do not acquire their medullary sheaths at the same time; hence the fibres can be grouped according to the dates at which they receive their medullary sheaths. (3) Staining nervous tissues by Golgi's method which allows the course and mode of termination of the axis-cylinder processes to be followed.

Fasciculi in the anterior funiculus.—The principal fasciculus is the *anterior cerebrospinal* (direct pyramidal tract), which is usually small, but varies in size inversely with the lateral cerebrospinal fasciculus. It lies close to the anterior median fissure, and is present only in the upper part of the medulla spinalis; gradually diminishing in size as it descends, it ends about

* Somewhat later a change, termed *chromatolysis*, takes place in the nerve-cells, and consists of a breaking down and ultimate disappearance of the Nissl bodies. The cell-body is swollen, the nucleus is displaced towards the periphery of the cell, and the part of the axon still attached to the altered cell is diminished in size and somewhat atrophied. Under favourable conditions the cell may reassume its normal appearance, and its axon may grow again.

the middle of the thoracic region. It consists of descending fibres which arise from cells in the motor area of the cerebral hemisphere of the same side, and which, as they run downwards in the medulla spinalis, cross in succession through the anterior white commissure to the opposite side, where they end by arborising around the motor cells in the anterior column.

In addition to the anterior cerebrospinal fasciculus there are strands of fibres in the anterior funiculus connecting certain ganglia in the brain with the grey substance of the medulla spinalis. One of these is the *vestibulospinal*, situated chiefly in the marginal part of the funiculus and mainly derived from the cells of Deiters' nucleus, one of the terminal nuclei of the vestibular nerve. Some fibres pass downwards from the corpora quadrigemina (*tectospinal*) and others are continuous with the medial longitudinal fasciculus.

The remaining fibres of the anterior funiculus constitute what is termed the *anterior proper fasciculus* (anterior basis bundle). It consists mainly of: (1) longitudinal intersegmental fibres which arise from cells in the grey substance, more especially from those of the medial group of the anterior column, and, after a longer or shorter course, re-enter the grey substance. Some of the fibres of this fasciculus pass upwards into the medial (posterior) longitudinal fasciculus (p. 790); (2) fibres arising from cells of the cerebellum and extending down the medulla spinalis to end around the cells of the anterior column—these fibres constitute an irregular tract, *cerebellospinal tract of Loewenthal*, disposed in the peripheral portions of the anterior and lateral proper fasciculi.

Fasciculi in the lateral funiculus.—1. **Descending fasciculi.**—(a) The *lateral cerebrospinal fasciculus* (crossed pyramidal tract) extends throughout the entire length of the medulla spinalis, and on transverse section appears as an oval area in front of the posterior column and medial to the direct cerebellar fasciculus. Its fibres arise from cells in the motor area of the cerebral hemisphere of the opposite side. They pass downwards in company with those of the anterior cerebrospinal fasciculus through the same side of the brain as that from which they originate, but they cross to the opposite side in the medulla oblongata and descend in the lateral funiculus of the medulla spinalis; they end by arborising around the motor cells in the anterior column.*

The anterior and lateral cerebrospinal fasciculi constitute the motor fasciculi of the medulla spinalis and have their origins in the motor cells of the cerebral cortex. They descend through the internal capsule of the cerebrum, traverse the cerebral peduncles and pons and enter the pyramid of the medulla oblongata. In the lower part of the latter about two-thirds of them cross the middle line and run downwards in the lateral funiculus as the lateral cerebrospinal fasciculus, while the remaining fibres do not cross, but are continued into the same side of the medulla spinalis, where they form the anterior cerebrospinal fasciculus. The fibres of the latter, however, cross the middle line in the anterior white commissure, and thus, generally speaking, all the motor fibres from one side of the brain ultimately reach the opposite side of the medulla spinalis. The proportion of fibres which cross in the medulla oblongata is not a constant one, and thus the anterior and lateral cerebrospinal fasciculi vary inversely in size. Sometimes the former is absent, and in such cases it may be presumed that the decussation of the motor fibres in the medulla oblongata has been complete. The fibres of these two fasciculi do not acquire their medullary sheaths until after birth. There is experimental and clinical evidence to show that the lateral cerebrospinal fasciculus contains a few fibres derived from the cerebral hemisphere of the same side (*uncrossed lateral cerebrospinal fibres*).

(b) The *rubrospinal fasciculus* (Monakow) lies on the ventral aspect of the lateral cerebrospinal fasciculus and on transverse section appears as a somewhat

* Schäfer (*Proc. Physiological Soc.* 1899) says it is probable that the fibres of the anterior and lateral cerebrospinal fasciculi are not related in this direct manner with the cells of the anterior column, but terminate by arborising round the cells at the base of the posterior column and the cells of Clarke's column, which in turn link them to the motor cells in the anterior column, usually of several segments of the cord. In consequence of these interposed neurons the fibres of the cerebrospinal fasciculi correspond, not to individual muscles, but to associated groups of muscles.

triangular area. Its fibres descend from the mid-brain, where they have their origin in the cells of the red nucleus of the tegmentum of the opposite side.

(c) The *tectospinal fasciculus* originates in the superior colliculus (upper quadrigeminal body) of the opposite side, and its fibres are partly intermingled with those of the rubrospinal fasciculus, and are partly contained in the anterior funiculus.

(d) The *olivospinal fasciculus* (Helweg) arises in the vicinity of the inferior olivary nucleus in the medulla oblongata and is seen only in the cervical region of the medulla spinalis, where it forms a small triangular area at the periphery, close to the most lateral of the anterior nerve-roots. Its exact origin and its mode of ending have not yet been definitely made out.

2. **Ascending fasciculi.**—(a) The *direct cerebellar tract of Flechsig* is situated at the periphery of the posterior portion of the lateral funiculus, and on transverse section appears as a flattened band reaching as far forwards as a line drawn transversely through the central canal of the medulla spinalis. Medially it is in contact with the lateral cerebrospinal fasciculus, behind, with the fasciculus of Lissauer. It begins about the level of the second or third lumbar nerve, increases in size as it ascends, and finally passes to the cerebellum through the restiform body. Its fibres are generally regarded as being the axons of the cells of the dorsal nucleus (Clarke's column); they receive their medullary sheaths about the sixth or seventh month of fetal life.

(b) The *superficial anterolateral fasciculus* (tract of Gowers) skirts the periphery of the lateral funiculus in front of the direct cerebellar fasciculus. In transverse section it is shaped somewhat like a comma, the expanded end lying in front of the lateral cerebrospinal fasciculus while the tail reaches forwards into the anterior funiculus. Its fibres come from the cells of the grey substance of the opposite side of the medulla spinalis and are derived from the cells of the dorsal nucleus and from other cells of the posterior column. The superficial anterolateral fasciculus begins about the level of the third pair of lumbar nerves, and, increasing in size as it ascends, can be followed into the medulla oblongata and pons. It consists of three fasciculi: (1) the *anterior spinocerebellar*, the largest of the three, passes to the cerebellum by way of the brachia conjunctiva; (2) the *spinothalamic* ends in the thalamus, and is sometimes termed the *secondary sensory fasciculus*; and (3) the *spinotectal* passes to the corpora quadrigemina.

(c) The *fasciculus of Lissauer* is a small strand situated at the tip of the posterior column close to the entrance of the posterior nerve-roots. It consists of fine fibres which do not receive their medullary sheaths until towards the close of foetal life; some of its fibres are said to remain non-medullated throughout life. It is usually regarded as being formed by some of the lateral fibres of the posterior nerve-roots, which ascend for a short distance in the tract and then enter the posterior column, but its fibres are myelinated later than those of the posterior nerve-roots, and do not undergo degeneration in locomotor ataxia; they are probably intersegmental in character.

(d) The *lateral proper fasciculus* (lateral basis bundle) constitutes the remainder of the lateral column, and is continuous in front with the anterior proper fasciculus. It consists chiefly of intersegmental fibres which arise from cells in the grey substance, and, after a longer or shorter course, re-enter the grey substance and ramify in it. Some of its fibres are, however, continued upwards into the brain under the name of the medial longitudinal fasciculus.

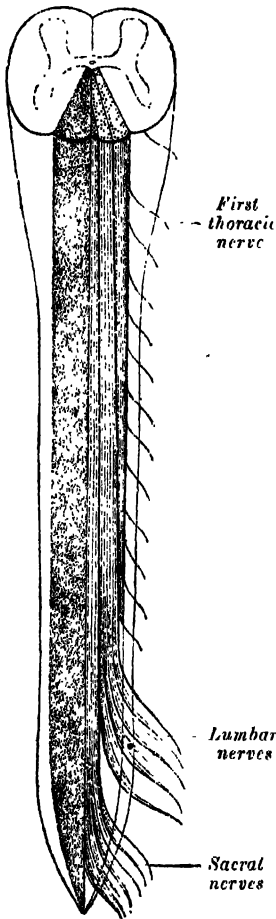
Fasciculi in the posterior funiculus.—This funiculus comprises two main fasciculi, viz. the fasciculus gracilis and the fasciculus cuneatus. These are separated from each other in the cervical and upper thoracic regions by the postero-intermediate septum, and consist mainly of ascending fibres derived from the posterior nerve-roots.

The *fasciculus gracilis* (tract of Goll) is wedge-shaped on transverse section, and lies next the posterior median septum, its base being at the surface of the medulla spinalis, and its apex directed towards the posterior grey commissure. It increases in size from below upwards (fig. 725), and consists of long thin fibres which are derived from the posterior nerve-roots, and ascend as far as the medulla oblongata, where they end in the nucleus gracilis.

The *fasciculus cuneatus* (tract of Burdach) is triangular on transverse section, and lies between the fasciculus gracilis and the posterior grey column, its base

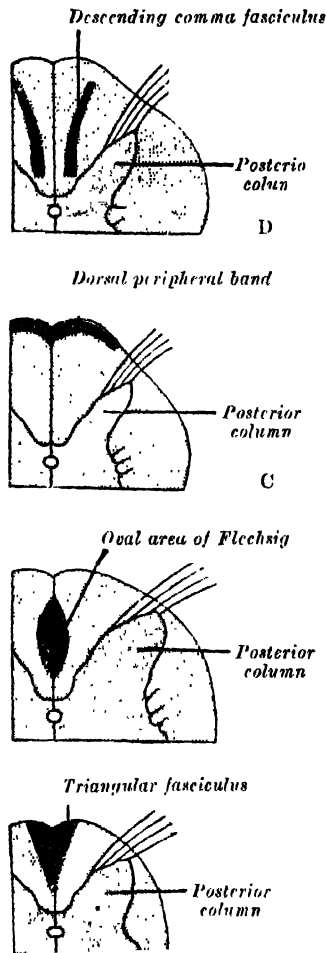
corresponding with the surface of the medulla spinalis. Its fibres, larger than those of the fasciculus gracilis, are mostly derived from the same source, viz. the posterior nerve-roots. Some of its fibres ascend for only a short distance, and, entering the grey substance, come into close relationship with the cells of the dorsal nucleus; others can be traced as far as the medulla oblongata, where they end in the nucleus gracilis and nucleus cuneatus.

FIG. 725.—Diagram showing the formation of the fasciculus gracilis. (Poirier.)



The medulla spinalis viewed from behind. To the left, the fasciculus gracilis is shaded. To the right, the drawing shows that the fasciculus gracilis is formed by the long ascending fibres of the posterior roots and that the sacral nerves lie next the median plane, the lumbar to their lateral side, and the thoracic still more laterally.

FIG. 726.—The descending fibres in the posterior funiculi, shown at different levels. (After Testut.)



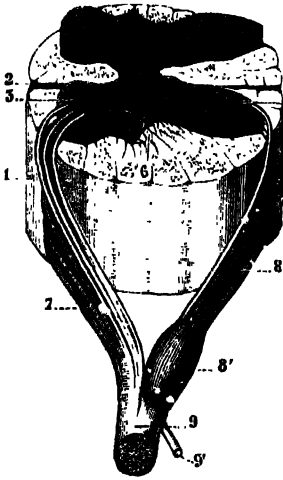
A. In the conus medullaris. B. In the lumbar region. C. In the lower thoracic region. D. In the upper thoracic region.

Occupying the ventral part of the posterior funiculus is a strand of fibres termed the *cornucommissural fasciculus*. It is somewhat crescentic on transverse section, and is placed between the posterior grey commissure and the posterior column; it is best marked in the lumbar region, but can be traced into the thoracic and cervical regions. Its fibres, derived from the cells of the posterior column, divide into ascending and descending branches which re-enter and ramify in the grey substance. This fasciculus has been found to preserve its integrity in certain cases of locomotor ataxia.

Descending fibres in the posterior funiculus (fig. 726).—The posterior funiculus

contains some descending fibres which occupy different parts at different levels. In the cervical and upper thoracic regions, they appear as a *comma-shaped fasciculus* in the medial part of the fasciculus cuneatus, the blunt edge of the fasciculus being directed forwards; in the lower thoracic region they form a *dorsal peripheral band* on the posterior surface of the funiculus; in the lumbar region, they are situated by the side of the posterior median septum, and appear on section as a semi-elliptical bundle, which, together with the corresponding bundle of the opposite side, forms the *oval area of Flechsig*; while in the conus medullaris they assume the form of a *triangular strand* in the posteromedial part of the fasciculus gracilis. These descending fibres are mainly intersegmental in character and derived from cells in the posterior column, but some consist of the descending branches of the posterior nerve-roots. The comma-shaped fasciculus was supposed to belong to the second category,

FIG. 727.—A spinal nerve with its anterior and posterior roots. (Testut.)



1. A portion of the medulla spinalis viewed from the left side. 2. Anterior median fissure. 3. Anterior column. 4. Posterior column. 5. Lateral column. 6. Formatio reticularis. 7. Anterior root. 8. Posterior root, with 8', its ganglion. 9. Spinal nerve; 9', its posterior division.

but against this view is the fact that it does not undergo descending degeneration when the posterior nerve-roots are destroyed.

Roots of the spinal nerves.—

As already stated, each spinal nerve possesses two roots, an anterior and a posterior, which are attached to the surface of the medulla spinalis opposite the corresponding column of gray substance (fig. 727); their fibres acquire their medullary sheaths about the fifth month of foetal life.

The *anterior nerve-root* consists of efferent fibres, which are the axons of the nerve-cells in the ventral part of the anterior column. A short distance from their origins, these axons are invested by medullary sheaths and, passing forwards, emerge in two or three irregular rows over an area which measures about 3 mm. in width.

The *posterior root* comprises six or eight fasciculi, attached in linear series along the posterolateral sulcus.

It consists of afferent fibres which

arise from the nerve-cells in a spinal ganglion. Each ganglion-cell gives off a single fibre which divides in a T-shaped manner into two processes, medial and lateral. The medial processes of the ganglion-cells pass into the medulla spinalis as the posterior roots of the spinal nerves, while the lateral are directed towards the periphery.

The posterior nerve-root enters the medulla spinalis in three chief bundles, medial, intermediate, and lateral. The *medial* strand passes directly into the fasciculus cuneatus; it consists of coarse fibres, which acquire their medullary sheaths about the fifth month of intra-uterine life; the *intermediate* strand consists of coarse fibres, which enter the gelatinous substance of Rolando; the *lateral* strand is composed of fine fibres, which are said to assume a longitudinal direction in the tract of Lissauer.

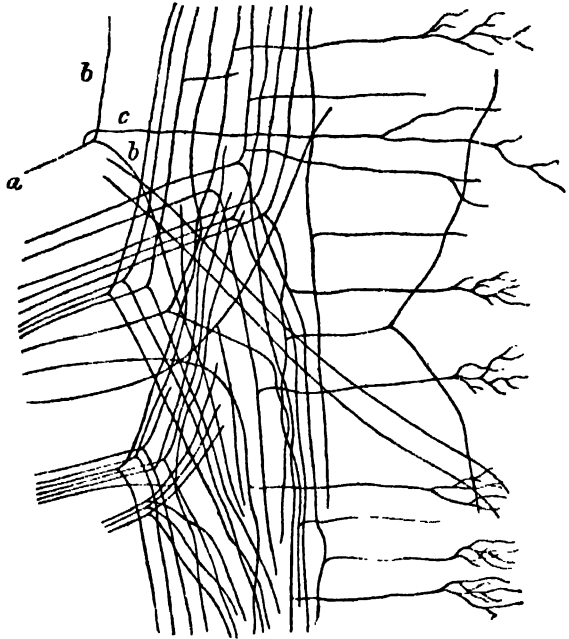
After entering the medulla spinalis, all the fibres of the posterior nerve-roots divide into ascending and descending branches, and these in their turn give off collaterals which enter the grey substance (fig. 728). The descending branches are short, and soon enter the grey substance. The ascending branches are grouped into long, short, and intermediate fibres: the long fibres ascend in the fasciculus cuneatus and fasciculus gracilis as far as the medulla oblongata, where they end by arborising around the cells of the cuneate and gracile nuclei; the short fibres run upwards for a distance of only 5 or 6 mm., and enter the grey substance; while the intermediate fibres, after a somewhat longer course, have a similar destination. All fibres entering the grey substance end by arborising around its nerve cells; in the thoracic region those of intermediate

length are especially associated with the cells of the dorsal nucleus. The collaterals which spring from the ascending and descending branches of the fibres of the posterior nerve-roots end by arborising around the cells in the anterior and posterior grey columns; in the thoracic region many of these collaterals arborise around the cells of the dorsal nucleus and the cells of the lateral grey column.

The long ascending fibres of the posterior nerve-roots pursue an oblique course upwards, being situated at first in the lateral part of the fasciculus cuneatus: higher up, they occupy the middle of this fasciculus, having been displaced by the accession of other entering fibres; while still higher, they ascend in the fasciculus gracilis. The upper cervical fibres do not reach this fasciculus, but are entirely confined to the fasciculus cuneatus. The localisation of these fibres is very precise: the sacral nerves lie in the medial part of the fasciculus gracilis and near its periphery, the lumbar nerves lateral to them, the thoracic nerves still more laterally; while the cervical nerves are confined to the fasciculus cuneatus (fig. 725).

The development of the medulla spinalis is described in the section on Embryology (pp. 86 to 90).

FIG. 728.—Posterior nerve-roots entering the medulla spinalis and dividing into ascending and descending branches. (Van Gehuchten.)



a. Nerve-fibre. b, c. Ascending and descending branches. d. Collateral arising from nerve-fibre.

Applied Anatomy.—Several cases have been recorded* in which a local doubling of the medulla spinalis has taken place. The condition is probably due to some interference with the development of the neural tube in the embryo; in a few it was associated with spina bifida, while in one recent case† the two parts were separated by a dermoid tumour. Other congenital abnormalities of the medulla spinalis occur in connexion with spina bifida (see p. 181), and *syringomyelia*. In this latter chronic condition an abnormal proliferation of the neuroglia takes place, generally near the central canal and in the cervical enlargement, and later this mass becomes absorbed, leaving an irregular cavity in its place. This gives rise to a number of interesting signs and symptoms, such as analgesia (or insensitiveness to pain), inability to distinguish between cold and heat, progressive atrophy in the muscles of the hands and arms, trophic changes in the bones and joints, and painless whitlows. Severe injuries to the medulla spinalis may occur in fractures or fracture-dislocations of the vertebral column anywhere above the second lumbar vertebra. If the medulla spinalis is completely crushed or torn across, total paralysis and anaesthesia of all parts of the body drawing their nerve supply from below the injured spot will follow, with loss of control over the actions of the bladder and rectum. The higher up such a lesion occurs, the worse the prognosis. Thus, in fracture of the atlas or epistropheus, the vital centres in the medulla oblongata are injured, and death occurs at once. If the origin of the phrenic nerve—mainly the fourth cervical—just escape in a case where the neck is broken, respiration will have to be carried on by the Diaphragm alone, and death is likely to ensue before long from pulmonary complications. When the back is broken in the lower thoracic region, life is not immediately threatened; but unless the patient is carefully nursed, death may follow at any time from the development of bed sores in the anaesthetic area, or from septic infection spreading up the ureters into the

* An analysis of these cases is given in the *Review of Neurology and Psychiatry*, Jan. 1916.

† Harriehausen, *D. Zeitschrift. f. Nervenheilk.* Bd. 36, Hft. 3 und 4, S. 268.

kidneys and secondary to the cystitis that is so prone to occur in patients who have no control over the bladder. *Inflammation of the medulla spinalis, or spinal myelitis*, sometimes follows influenza or one of the acute specific fevers. A transverse patch of such myelitis extending completely across the medulla spinalis produces more or less complete interruption of the passage of nervous impulses through it. Hence it will occasion more or less complete paralysis and anaesthesia of the parts of the body obtaining their nerve-supply from below it, and, in addition, a zone of cutaneous hyperaesthesia at its level, in consequence of the irritation of the sensory fibres entering the inflamed region of the medulla spinalis. The disease mainly attacking children, and known as *infantile spinal paralysis*, or *acute anterior poliomyelitis*, is a bacterial infection of the pia mater that spreads into the medulla spinalis along the blood-vessels, and destroys groups of the motor neurons aggregated in the anterior column. Destruction of the cells causes rapid and permanent paralysis of the muscles innervated, and groups of muscles in one or more of the limbs are commonly picked out for attack. The affected limbs are thus partially paralysed, and their subsequent growth and nutrition both suffer. Further, the muscles that normally antagonise the affected groups of muscles, finding their actions unopposed, tend to assume a state of spastic contraction. In consequence, much dwarfing and deformity follow later, and may demand for their relief such operations as tenotomy, the transplantation of tendons, or even amputation.

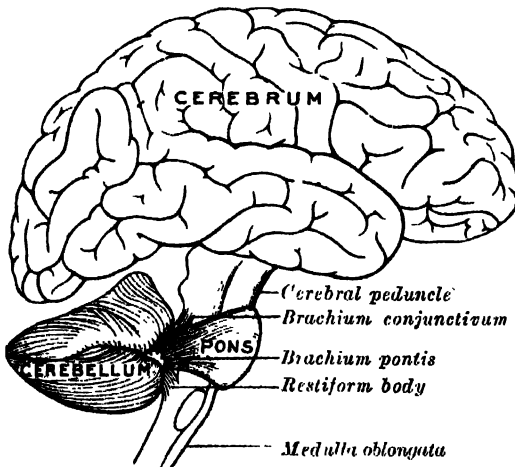
Inflammation of the ganglia on one or more of any of the posterior nerve-roots is the cause of *shingles** or herpes zoster, in which there is a painful eruption of groups of cutaneous vesicles corresponding to the distribution of the nerves derived from the affected ganglia. It is commonest along the course of the intercostal nerves; the eruption is often preceded and followed, as well as accompanied, by girdle pains, and in old people these may be prolonged and serious in character. Herpes is the analogue on the sensory side to anterior poliomyelitis on the motor side of the nervous system.

THE ENCEPHALON OR BRAIN

GENERAL CONSIDERATIONS AND DIVISIONS

The encephalon, or brain, is the upper, expanded part of the central nervous system, and is contained within the cranium. In the early embryo it consists

FIG. 729.—Scheme showing the connexions of the several parts of the brain. (After Schwalbe.)



of three hollow vesicles, termed the *rhombencephalon* or *hind-brain*, the *mesencephalon* or *mid-brain*, and the *prosencephalon* or *fore-brain*; and the parts derived from each of these can be recognised in the adult (fig. 729). The wall of the rhombencephalon is modified to form the medulla oblongata, pons, and cerebellum, while its cavity is expanded to form the fourth ventricle. The mesencephalon forms only a small part of the adult brain; its cavity becomes the cerebral aqueduct (aqueduct of Sylvius), which serves as a tubular communication between the third and fourth ventricles; while its walls

are thickened to form the corpora quadrigemina and the cerebral peduncles. The prosencephalon undergoes great modification: its anterior part or telencephalon expands laterally as two hollow vesicles the cavities of which become the lateral ventricles, while the surrounding walls form the cerebral hemispheres and their commissures; the cavity of the posterior part or diencephalon forms the greater part of the third ventricle, and from its walls are developed most of the structures which bound that cavity. Further details regarding these

* Lat. *cingulum*, a belt.

important changes are given in the chapter on Embryology, and the student is recommended to read pages 90 to 100 before commencing the study of the brain.

THE RHOMBENCEPHALON OR HIND-BRAIN

The **rhombencephalon** or **hind-brain** occupies the posterior fossa of the cranial cavity and lies below a fold of dura mater, named the **tentorium cerebelli**. It consists of (a) the *myelencephalon*, comprising the medulla oblongata and the lower part of the fourth ventricle; (b) the *metencephalon*, consisting of the pons, cerebellum, and the intermediate part of the fourth ventricle; and (c) the *isthmus rhombencephali*, a constricted portion immediately adjoining the mesencephalon and including the brachia conjunctiva of the cerebellum, the anterior medullary velum, and the upper part of the fourth ventricle.

THE MEDULLA OBLONGATA

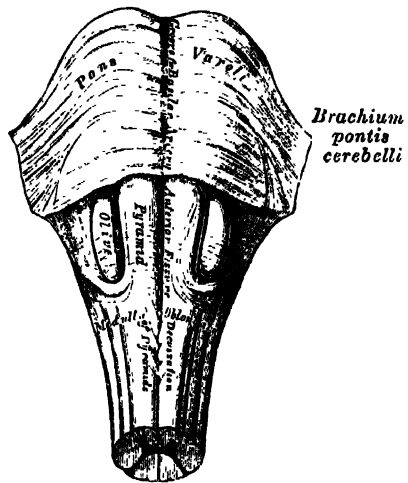
The **medulla oblongata**, the lowest division of the brain, is extremely complex in structure, since it gives attachment to many of the cerebral nerves, and forms the connecting link between the medulla spinalis below and the cerebrum and cerebellum above.

It extends from the lower margin of the pons to a plane passing transversely below the pyramidal decussation and above the first pair of cervical nerves; this plane corresponds with the upper border of the atlas behind, and the middle of the dens of the epistropheus in front; at this level the medulla oblongata is continuous with the medulla spinalis. The anterior surface of the medulla oblongata is separated from the basilar part of the occipital bone and the upper part of the dens of the epistropheus by the membranes of the brain and the occipito-axial ligaments. Its posterior surface is received into the fossa between the hemispheres of the cerebellum, and the upper portion of it forms the lower part of the floor of the fourth ventricle. The vertebral arteries pass upwards and forwards in relation to its lateral surfaces; they then curve forwards to its anterior surface and unite at the lower border of the pons to form the basilar artery.

The medulla oblongata is pyramidal in shape (fig. 730), its broad extremity being directed upwards towards the pons, while its narrow lower end is continuous with the medulla spinalis. It measures about 3 cm. in length, about 2 cm. transversely at its widest part, and about 1.25 cm. anteroposteriorly. The central canal of the medulla spinalis is prolonged into its lower half, and then opens into the cavity of the fourth ventricle; the medulla oblongata may therefore be divided into a lower *closed part* containing the central canal, and an upper *open part* corresponding with the lower portion of the fourth ventricle. Its anterior and posterior surfaces are marked by median fissures.

The **anterior median fissure** contains a fold of pia mater, and extends along the entire length of the medulla oblongata; below, it is continuous with the anterior median fissure of the medulla spinalis; above, it ends at the lower border of the pons in a small triangular expansion, termed the *foramen cæcum*.

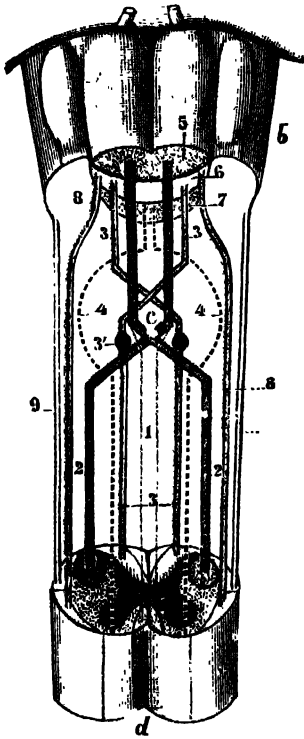
FIG. 730.—The medulla oblongata and pons. Anterior surface.



Its lower part is interrupted by bundles of fibres which cross obliquely from one side to the other, and constitute the *pyramidal decussation*. Some fibres, termed the *external arcuate fibres*, emerge from the fissure above this decussation and curve lateralwards and upwards over the surface of the medulla oblongata.

The *posterior median fissure* is a narrow groove which exists only in the closed part of the medulla oblongata; it is continuous below with the *posterior median sulcus* of the medulla spinalis, becomes gradually shallower from below upwards, and finally ends about the middle of the medulla oblongata, where the central canal expands into the cavity of the fourth ventricle.

FIG. 731.—Decussation of the pyramids. Scheme showing the passage of various fasciculi from the medulla spinalis to the medulla oblongata. (Testut.)



a. Pons. b. Medulla oblongata. c. Decussation of the pyramids. d. Section of cervical part of medulla spinalis. 1. Anterior cerebrospinal fasciculus (in red). 2. Lateral cerebrospinal fasciculus (in red). 3. Fasciculus gracilis and fasciculus cuneatus (in blue). 3'. Nucleus gracilis and nucleus cuneatus. 4. Anterolateral proper fasciculus (in dotted line). 5. Pyramid. 6. Lemniscus. 7. Medial longitudinal fasciculus. 8. Superficial anterolateral fasciculus (in blue). 9. Direct cerebellar tract (in yellow).

between it and the pons the fibres of the abducent nerve emerge; below, it tapers into the anterior funiculus of the medulla spinalis, with which, at first sight, it appears to be directly continuous.

The two pyramids contain the motor fibres which pass from the brain to the medulla spinalis. When traced downwards, two-thirds, or more, of these fibres leave the pyramids in successive bundles, and decussate in the anterior median fissure, forming what is termed the *pyramidal decussation*. Having crossed the middle line, they pass down in the posterior part of the lateral funiculus of the medulla spinalis as the lateral cerebrospinal fasciculus. The remaining fibres—i.e. those which occupy the lateral part of the pyramid—do not cross the middle line, but descend as the anterior cerebrospinal

These two fissures divide the closed part of the medulla oblongata into lateral halves, each presenting elongated eminences which, on surface view, are continuous with the funiculi of the medulla spinalis. In the open part the halves are separated by the anterior median fissure, and by a median *raphe* which extends from the bottom of the fissure to the median sulcus of the rhomboid fossa or floor of the fourth ventricle. Further, certain of the cerebral nerves pass through the substance of the medulla oblongata, and are attached to its surface in series with the roots of the spinal nerves; thus, the fibres of the hypoglossal nerve correspond in position with the anterior roots of the spinal nerves, and emerge in linear series from a furrow termed the *anterolateral sulcus*. Similarly, the accessory, vagus, and glossopharyngeal nerves correspond with the posterior roots of the spinal nerves, and are attached to the bottom of a sulcus named the *posterolateral sulcus*. Advantage is taken of this arrangement to subdivide each half of the medulla oblongata into three regions, anterior, middle, and posterior. Although these three regions appear to be directly continuous with the corresponding funiculi of the medulla spinalis, they do not necessarily contain the same nerve-fibres since some of the fasciculi of the medulla spinalis end in the medulla oblongata, while others alter their course in passing through it.

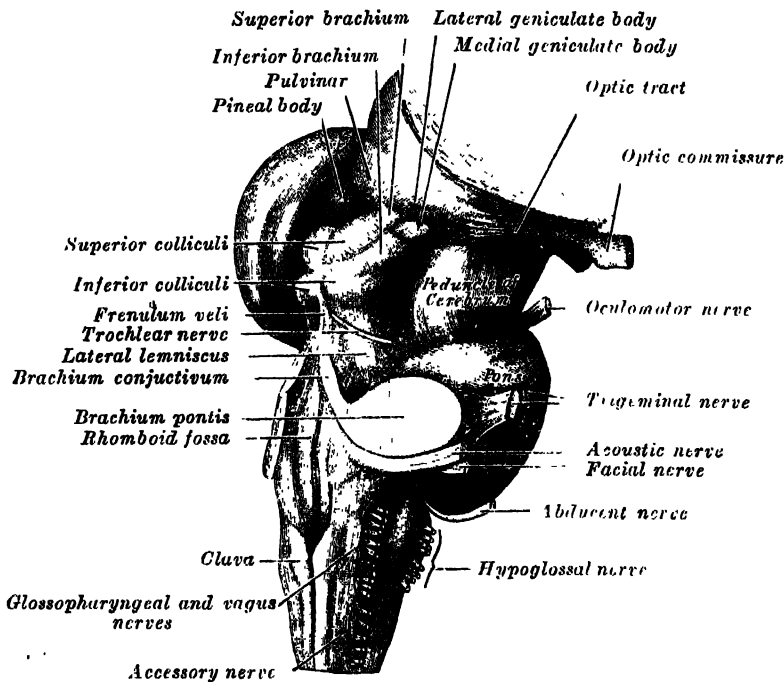
The anterior region of the medulla oblongata (fig. 730) is named the *pyramid*, and lies between the anterior median fissure and the anterolateral sulcus. Its upper end is slightly constricted, and

fasciculus (fig. 731) into the anterior funiculus of the same side of the medulla spinalis.

The greater part of the anterior proper fasciculus of the medulla spinalis is continued upwards through the medulla oblongata under the name of the *medial longitudinal fasciculus*.

The lateral region of the medulla oblongata (fig. 732) is limited in front by the anterolateral sulcus and the roots of the hypoglossal nerve, and behind by the posterolateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves. Its upper part consists of a prominent oval mass which is named the olive, while its lower part is of the same width as the lateral funiculus of the medulla spinalis, and appears on the surface to be a direct continuation of it. As a matter of fact, only a portion of the lateral funiculus of the medulla spinalis is continued upwards into this region, for the lateral

FIG. 732.—The hind-brain and mid-brain; posterolateral view.



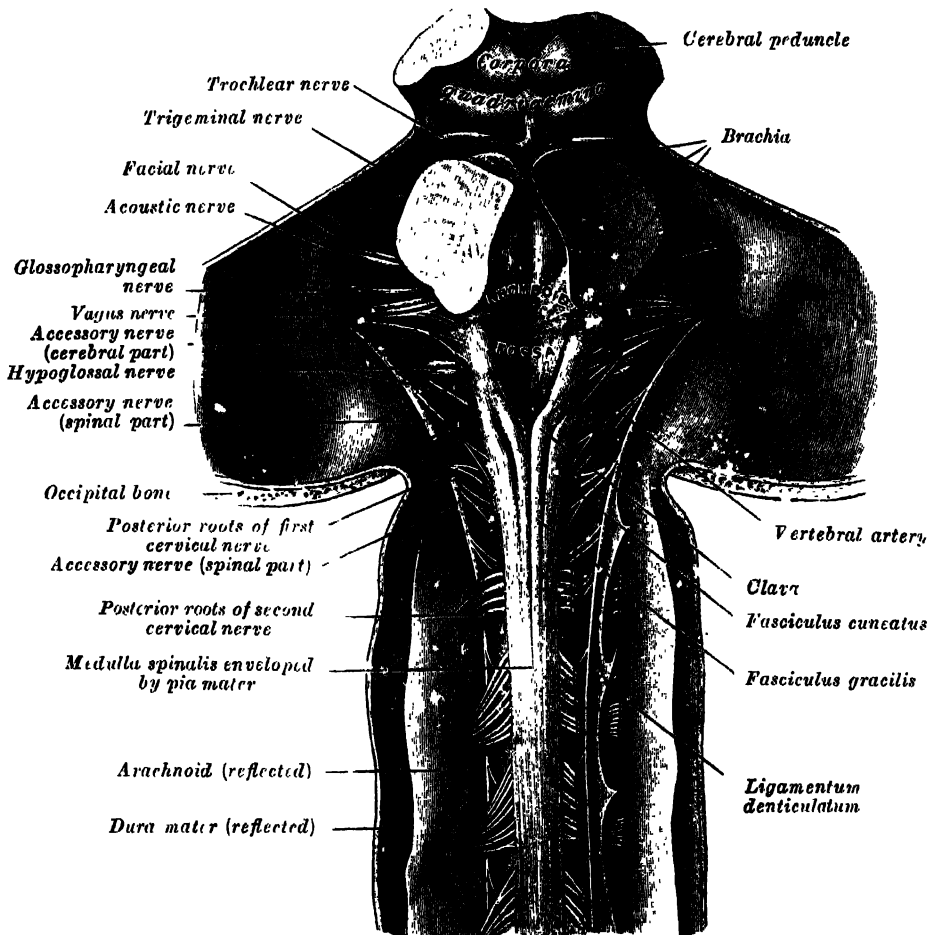
cerebrospinal fasciculus passes into the pyramid of the opposite side, and the direct cerebellar tract is carried into the restiform body in the posterior region. The remainder of the lateral funiculus, which consists chiefly of the lateral proper fasciculus and the superficial anterolateral fasciculus, can be traced into the lateral region. Most of these fibres dip beneath the olive and disappear from the surface; but a small strand remains superficial, and ascends between the olive and the posterolateral sulcus. In a depression at the upper end of this strand is the acoustic nerve.

The *olive* is situated lateral to the pyramid, from which it is separated by the anterolateral sulcus and the fibres of the hypoglossal nerve. Behind, it is separated from the posterolateral sulcus by the small superficial strand of the lateral funiculus already referred to. It is about 1.25 cm. long, and between its upper end and the pons there is a slight depression to which the roots of the facial nerve are attached. The external arcuate fibres wind backwards across the lower part of the pyramid and olive and enter the restiform body.

The posterior region of the medulla oblongata (fig. 733) lies behind the posterolateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves, and, like the lateral region, is divisible into a lower and an upper portion.

The lower part is limited behind by the posterior median fissure, and consists of the *fasciculus gracilis* and the *fasciculus cuneatus*, the direct upward prolongations of the posterior funiculi of the medulla spinalis. The *fasciculus gracilis* is placed parallel to and along the side of the posterior median fissure, and is separated from the *fasciculus cuneatus* by the postero-intermediate sulcus and septum. The *fasciculus gracilis* and *fasciculus cuneatus* are at first vertical; but at the lower part of the rhomboid fossa they diverge from the middle line in a V-shaped manner, and each presents an elongated swelling.

FIG. 733.—The upper part of the medulla spinalis and the hind- and mid-brains; exposed from behind.

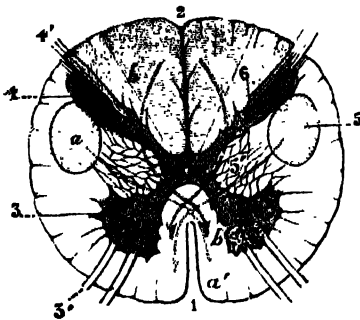


The swelling on the *fasciculus gracilis* is named the *clava*, and is produced by a subjacent nucleus of grey matter, the *nucleus gracilis*; that on the *fasciculus cuneatus* is termed the *cuneate tubercle*, and is caused by a grey nucleus, named the *nucleus cuneatus*. The fibres of these two fasciculi end by arborising around the cells in their respective nuclei. A third elevation, named the *tuberculum cinereum* (tubercle of Rolando), is present in the lower part of the posterior region of the medulla oblongata. It lies between the *fasciculus cuneatus* and the roots of the accessory nerve, and is narrow below but wider above; it ends superiorly at a distance of about 1.25 cm. below the pons. It is produced by a nucleus of grey substance which is continuous below with the *substantia gelatinosa* of Rolando, and in which the fibres of the *tractus spinalis*, or spinal root, of the trigeminal nerve ends; these fibres separate it from the surface of the medulla oblongata.

The *upper part* of the posterior region of the medulla oblongata is occupied by the *restiform body*, a thick rope-like strand situated between the lower part of the fourth ventricle and the roots of the glossopharyngeal and vagus nerves. The two restiform bodies connect the medulla spinalis and medulla oblongata with the cerebellum, and are sometimes named the *inferior peduncles of the cerebellum*. As they ascend, they diverge from one another, and assist in forming the lower parts of the lateral boundaries of the fourth ventricle: higher up, they are directed backwards, each passing to the corresponding cerebellar hemisphere. Near their entrance into the cerebellum they are crossed by several strands of fibres, which run to the median sulcus of the rhomboid fossa and are named the *striae medullares*. The restiform body appears to be the upward continuation of the fasciculus gracilis and fasciculus cuneatus, but the fibres of these fasciculi end in the nucleus gracilis and nucleus cuneatus: its constitution will be subsequently discussed.

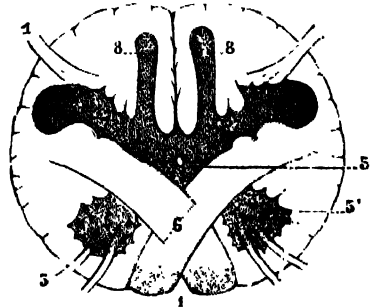
Internal structure of the medulla oblongata.—Although the external form of the medulla oblongata bears a certain resemblance to that of the upper

FIG. 734.—Section of the medulla oblongata below the level of the decussation of the pyramids. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Anterior column (in red), with 3', anterior root. 4. Posterior column (in blue), with 4', posterior root. 5. Lateral cerebrospinal fasciculus. 6. Posterior funiculus. The arrow, *aa'*, indicates the course of the decussation of the pyramids; the arrow, *bb'*, that of the decussation of the lemniscus.

FIG. 735.—Section of the medulla oblongata at the level of the decussation of the pyramids. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Motor roots. 4. Sensory roots. 5. Base of the anterior column, from which the head (5') has been detached by the lateral cerebrospinal fasciculus. 6. Decussation of the pyramids. 7. Posterior columns (in blue). 8. Nucleus gracilis.

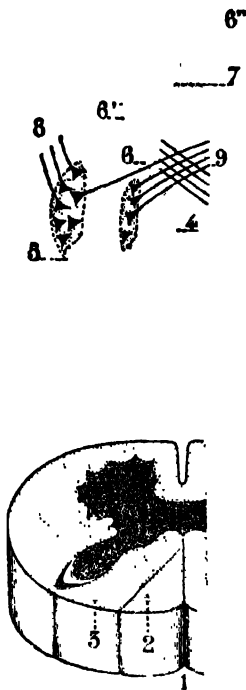
part of the medulla spinalis, its internal structure differs widely from that of the latter, and this for the following principal reasons: (1) certain fasciculi of nerve-fibres which extend from the medulla spinalis to the brain, or vice versa, undergo a rearrangement in their passage through the medulla oblongata; (2) other fasciculi of the medulla spinalis end in the medulla oblongata; (3) new fasciculi originate in the grey substance of the medulla oblongata and pass to different parts of the brain; (4) the grey substance, which in the medulla spinalis forms a continuous H-shaped column, is greatly modified and subdivided in the medulla oblongata, where also new masses of grey substance are added: (5) on account of the opening out of the central canal of the medulla spinalis, certain parts of the grey substance, which in the medulla spinalis were more or less centrally situated, are displayed in the rhomboid fossa; (6) the medulla oblongata is intimately associated with many of the cerebral nerves, some arising from, and others ending in, nuclei within its substance.

The internal structure of the medulla oblongata is best studied in a series of transverse (figs. 738, 739) and longitudinal sections. A short description of the course taken by the principal fasciculi, and of the arrangement of the grey substance, will now be given.

The cerebrospinal fasciculi.—The downward course of these fasciculi from the pyramids of the medulla oblongata and their partial decussation have already been described (p. 755). In crossing to reach the lateral funiculus

of the opposite side, the fibres of the lateral cerebrospinal fasciculi run backwards through the anterior columns, and separate the head of each of these columns from its base (figs. 734, 735). The base retains its position in relation to the ventral aspect of the central canal, and, when the latter opens into the fourth ventricle, appears in the rhomboid fossa, or floor of the ventricle, close to the middle line, where it forms the nuclei of the hypoglossal and abducent nerves; while, above the level of the ventricle it exists as the nuclei of the trochlear and oculomotor nerves in relation to the floor of the cerebral aqueduct. The head of the column is pushed lateralwards and forms the *nucleus ambiguus* which gives origin from below upwards to the cerebral

FIG. 736.—Superior terminations of the fasciculus gracilis and fasciculus cuneatus of the medulla spinalis. (Testut.)

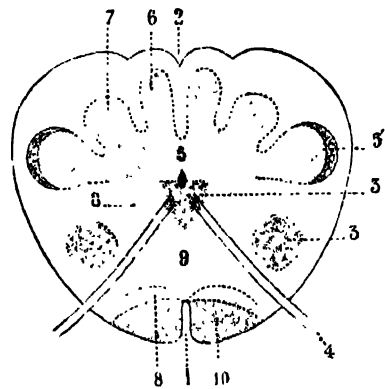


1. Posterior median sulcus. 2, 2'. Fasciculus gracilis. 3. Fasciculus cuneatus. 4. Nucleus gracilis. 5. Nucleus cuneatus. 6, 6'. Sensory fibres forming the lemniscus. 7. Sensory decussation. 8. Cerebellar fibres, uncrossed. 9. Cerebellar fibres, crossed.

part of the medulla oblongata, where they end respectively in the nucleus gracilis and nucleus cuneatus. These two nuclei are continuous with the central grey substance of the medulla spinalis, and may be regarded as dorsal projections of it, each being covered superficially by the fibres of the corresponding fasciculus. On transverse section (fig. 738), the nucleus gracilis appears as a single, more or less quadrangular mass, while the nucleus cuneatus consists of two parts: a larger, somewhat triangular, *medial nucleus*, composed of small or medium-sized cells, and a smaller *lateral nucleus* containing large cells.

The fibres of the fasciculus gracilis and fasciculus cuneatus end by arborising around the cells of these nuclei (fig. 736). From the cells of the nuclei new fibres arise; some of these are continued as the external arcuate fibres into the restiform body of the same side, and through it to the cerebellum, but most of them pass forwards as the *internal arcuate fibres* through the neck of the

FIG. 737.—Transverse section passing through the sensory decussation (decussation of the lemniscus). (Schematic.) (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3, 3'. Head and base of the anterior column (in red). 4. Hypoglossal nerve. 5. Bases of the posterior column. 5'. Tuberculum cinereum (tubercle of Rolando). 6. Nucleus gracilis. 7. Nucleus cuneatus. 8. 8. Lemniscus. 9. Sensory decussation. 10. Pyramid.

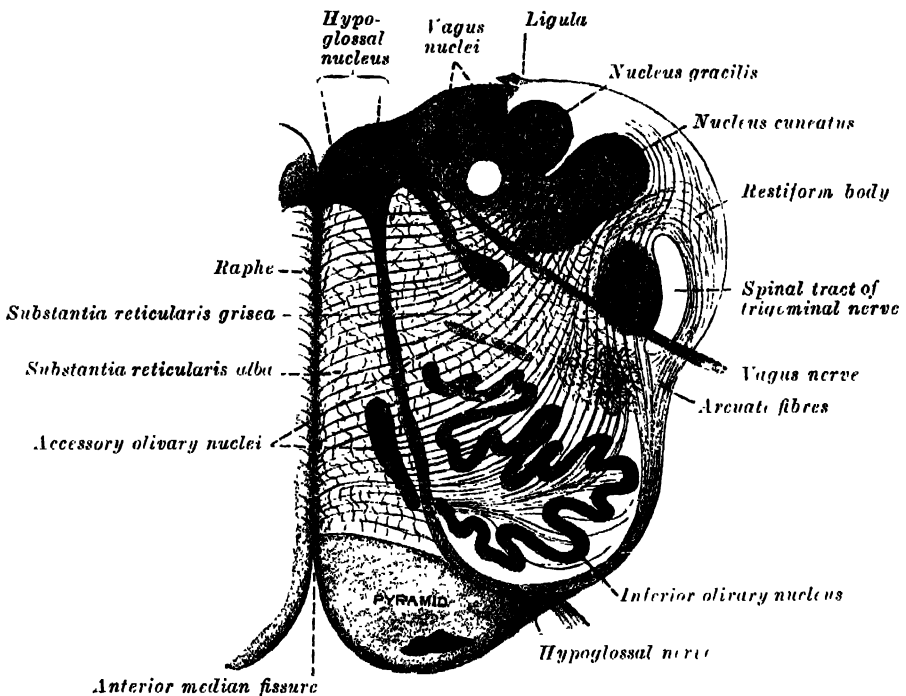
part of the accessory nerve and the motor fibres of the vagus and glossopharyngeal nerves; higher up, the head of the column is represented by the motor nuclei of the facial and trigeminal nerves.

The *fasciculus gracilis* and *fasciculus cuneatus* constitute the posterior sensory fasciculi of the medulla spinalis; they are prolonged upwards into the lower

posterior column, thus cutting off its head from its base (fig. 737). Curving forwards, they decussate in the middle line with the corresponding fibres of the opposite side, and run upwards immediately behind the cerebrospinal fibres, as a flattened band, named the *lemniscus* or *fillet*. The decussation of those sensory fibres is situated above that of the motor fibres, and constitutes the *decussation of the lemniscus* or *sensory decussation*. The lemniscus is joined by the spinothalamic fasciculus (p. 756), the fibres of which are derived from the cells of the posterior grey column of the opposite side of the medulla spinalis.

The base of the posterior column at first lies on the dorsal aspect of the central canal, but when the latter opens into the fourth ventricle, it appears in the lateral part of the rhomboid fossa. It forms the terminal nuclei of the

FIG. 738.—Section of the medulla oblongata at about the middle of the olive. (Schwalbe.)



sensory fibres of the vagus and glossopharyngeal nerves, and is associated with the vestibular part of the acoustic nerve and the sensory root of the facial nerve. Still higher, it forms a mass of pigmented cells—the *locus ceruleus*—in which some of the sensory fibres of the trigeminal nerve appear to end. The head of the posterior column forms a long nucleus, in which the fibres of the spinal tract of the trigeminal nerve largely end.

The **direct cerebellar fasciculus** leaves the lateral region of the medulla oblongata; most of its fibres are carried backwards into the restiform body of the same side, and through it are conveyed to the cerebellum; but some run upwards with the fibres of the lemniscus, and, reaching the inferior colliculus, undergo decussation, and are carried to the cerebellum through the *brachium conjunctivum*.

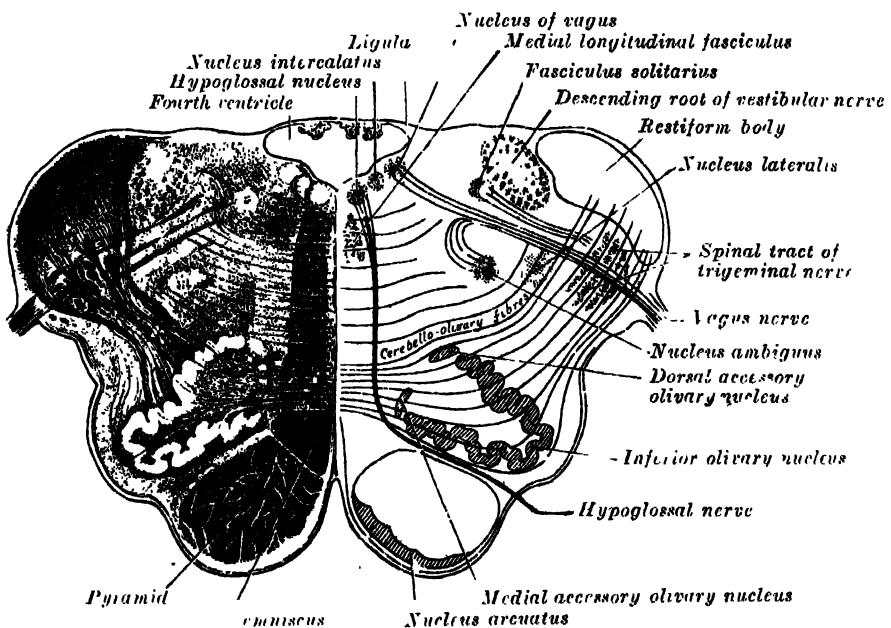
The **proper fasciculi** (basis bundles) of the anterior and lateral funiculi largely consist of intersegmental fibres, which link together the different segments of the medulla spinalis; they assist in the production of the *formatio reticularis* of the medulla oblongata, and many of them are accumulated into a fasciculus which runs up close to the median raphe between the lemniscus

and the rhomboid fossa; this strand is named the *medial longitudinal fasciculus*, and will be again referred to.

Grey substance of the medulla oblongata (figs. 738, 739).—In addition to the gracile and cuneate nuclei, there are several other nuclei to be considered. Some of these are traceable from the grey substance of the medulla spinalis, while others are unrepresented in it.

1. The *hypoglossal nucleus* is derived from the base of the anterior column; in the lower, closed part of the medulla oblongata it is situated on the ventrolateral aspect of the central canal; but in the upper, open part it approaches the rhomboid fossa, where it lies close to the middle line, under an eminence named the *trigonum hypoglossi* (fig. 753). The nucleus measures about 2 cm. in length, and consists of large multipolar nerve-cells the axons of which constitute the

FIG. 739.—Transverse section of the medulla oblongata below the middle of the olive.



roots of the hypoglossal nerve. These nerve-roots pass forward between the anterior and lateral regions of the medulla oblongata, and emerge at the anterolateral sulcus.

2. The *motor nucleus* (figs. 740, 741), common to the *glossopharyngeal*, *vagus*, and cerebral part of the *accessory nerves*, is named the *nucleus ambiguus*. It represents the head of the anterior column, lies deeply in the formation *reticularis grisea*, and extends throughout nearly the whole length of the medulla oblongata.

3. The terminal nucleus of the sensory fibres of the *glossopharyngeal* and *vagus* represents the base of the posterior column (figs. 740, 742). It measures about 2 cm. in length, and in the lower, closed part of the medulla oblongata is situated behind the hypoglossal nucleus; whereas in the upper, open part it lies lateral to that nucleus, and corresponds to an area, named the *ala cinerea* or *trigonum vagi*, in the rhomboid fossa.

4. The *nuclei of the acoustic nerve* are described on p. 775.

5. The *olivary nuclei* (fig. 738) are three in number on either side of the middle line, viz. the *inferior olivary nucleus*, and the *medial and dorsal accessory olivary nuclei*; they consist of small, round, yellowish cells and numerous fine nerve-fibres. (a) The *inferior olivary nucleus* is the largest, and is situated within the olive. It consists of a grey folded lamina arranged

in the form of an incomplete capsule, opening medially by an aperture called the *hilum*; emerging from the hilum are numerous fibres which collectively constitute the *peduncle of the olive*. (b) The *medial accessory olivary nucleus* lies between the inferior olivary nucleus and the pyramid, and forms a curved lamina, the concavity of which is directed laterally. The fibres of the hypoglossal nerve, as they traverse the medulla, pass between the medial accessory and the inferior olivary nuclei. (c) The *dorsal accessory olivary nucleus* is the smallest, and appears on transverse section as a curved lamina behind the inferior olivary nucleus.

The inferior olivary nucleus is connected—(1) with that of the opposite side by fibres which cross through the raphe; (2) with the anterior column of the same side of the medulla spinalis by the *spino-olivary fasciculus*; (3) with the thalamus of the cerebrum by the *cerebro-olivary fasciculus* which passes through the pons and tegmentum; (4) with the opposite cerebellar hemisphere by the *cerebello-olivary fasciculus* (fig. 743), the fibres of which cross the raphe and turn backwards to enter the deep part of the restiform body. Removal of one cerebellar hemisphere is followed by atrophy of the opposite olivary nucleus.

6. The *nucleus arcuatus* is described below with the external arcuate fibres.

Restiform bodies.—The position of the restiform bodies has already been described (p. 765). Each comprises: (1) the direct cerebellar tract, which ascends from the lateral funiculus of the same side of the medulla spinalis; (2) the cerebello-olivary fasciculus described above; (3) descending cerebellar fibres, many of which are disseminated throughout the peripheral part of the anterior and lateral funiculi of the medulla spinalis, while others pass to the motor nuclei of the cerebral nerves; and (4) the external arcuate fibres.

The *external arcuate fibres* vary as to their prominence in different cases: in some they form an almost continuous layer covering the pyramid and olive while in others they are barely visible on the surface. They arise from the cells of the nucleus gracilis and nucleus cuneatus, pass forwards through the formatio reticularis, and decussate in the middle line. Most of them reach the surface by way of the anterior median fissure, and arch backwards over the pyramid. Reinforced by others which emerge between the pyramid and olive, they pass backwards over the olive and lateral region of the medulla

FIG. 740.—The nuclei of the cerebral nerves schematically represented; dorsal view. Motor nuclei, in red; sensory in blue. (The olfactory and optic centres are not represented.)

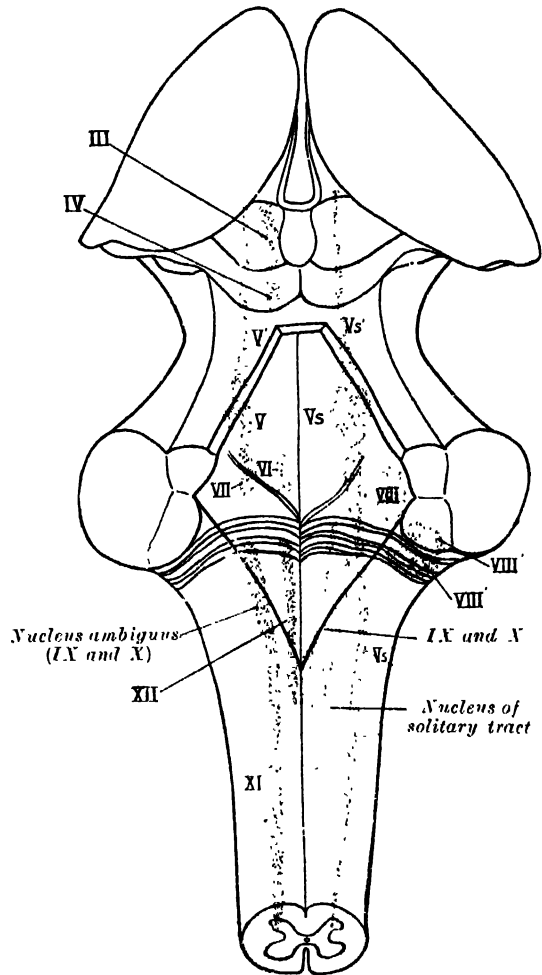


FIG. 741.—The nuclei of origin of the cerebral motor nerves schematically represented; lateral view.

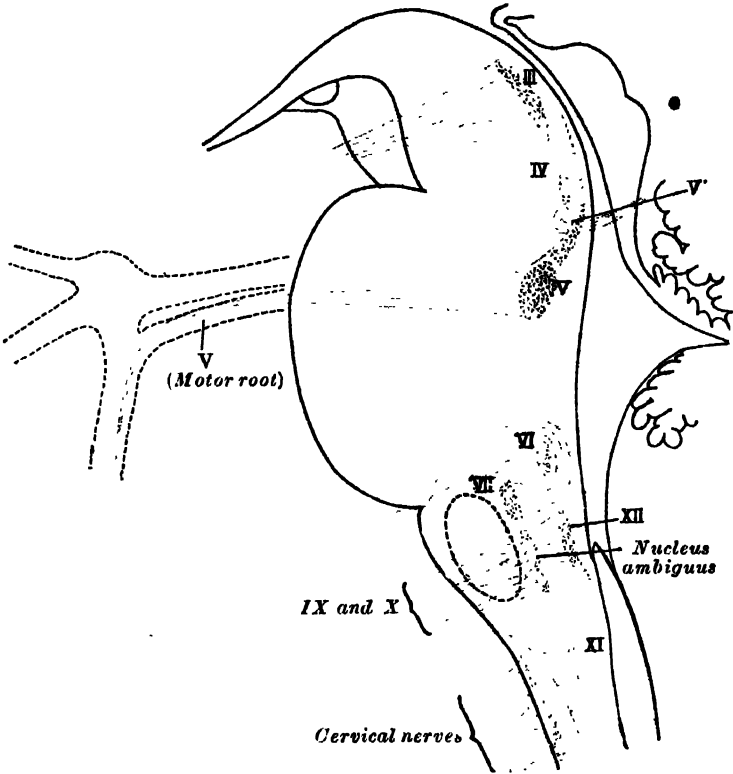
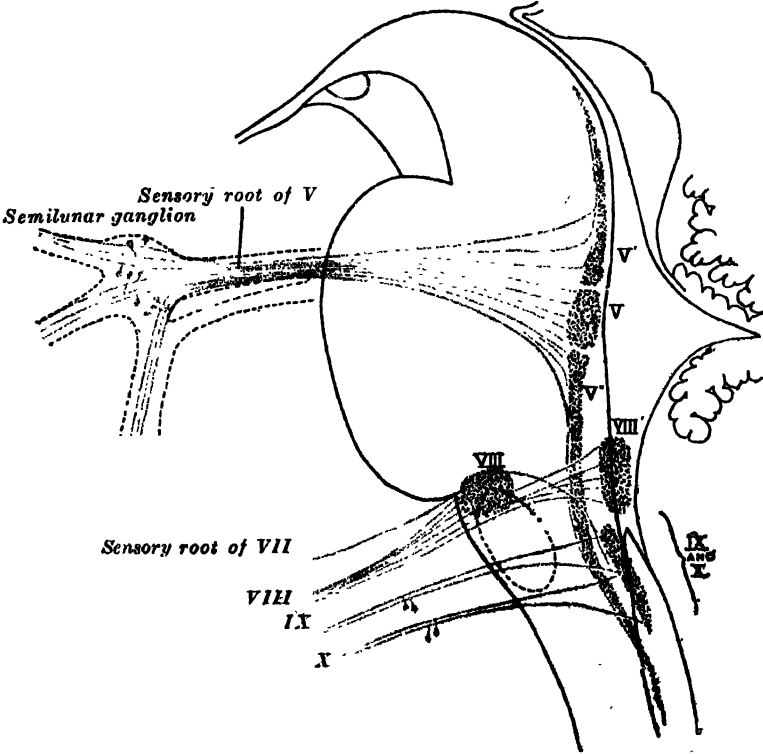


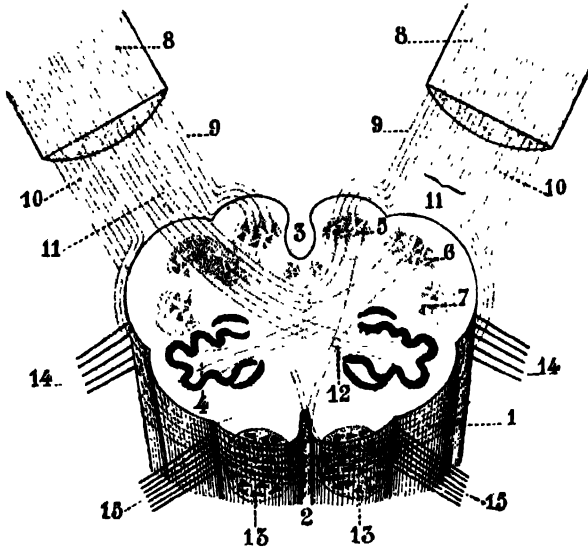
FIG. 742.—The primary terminal nuclei of the afferent (sensory) cerebral nerves schematically represented; lateral view. The olfactory and optic centres are omitted.



oblongata, and enter the restiform body. They thus connect the cerebellum with the nucleus gracilis and nucleus cuneatus of the opposite side. As the fibres arch across the pyramid, they enclose a small nucleus which lies in front of and medially to the pyramid. This is named the *nucleus arcuatus*, and is serially continuous above with the nuclei pontis: it contains small fusiform cells, around which some of the arcuate fibres end, and from which others arise.

A few fibres are said to arise from the nucleus gracilis and nucleus cuneatus and to pass to the restiform body of the same side.

FIG. 743.—Diagram showing the course of the arcuate fibres. (Testut.)



1. Medulla oblongata, anterior surface. 2. Anterior median fissure. 3. Fourth ventricle. 4. Inferior olivary nucleus, with the accessory olivary nuclei. 5. Nucleus gracilis. 6. Nucleus cuneatus. 7. Spinal tract and nucleus of trigeminal nerve. 8. Restiform bodies. 9. Posterior external arcuate fibres. 10. Anterior external arcuate fibres. 11. Cerebello-olivary fasciculus. 12. Peduncle of inferior olivary nucleus. 13. Nucleus arcuatus. 14. Vagus nerve. 15. Hypoglossal nerve.

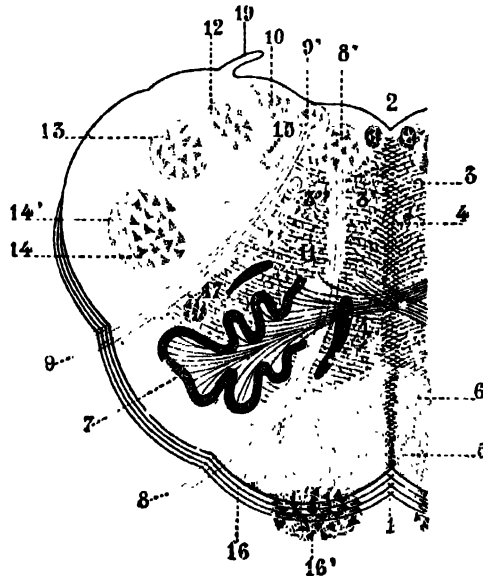
Formatio reticularis (fig. 744).—This term is applied to the coarse reticulum which occupies the anterior and lateral regions of the medulla oblongata. It is situated behind the pyramid and olive, extending laterally as far as the restiform bodies, and dorsally to within a short distance of the rhomboid fossa. The reticulum is caused by the intersection of bundles of fibres running at right angles to each other, some being longitudinal, others more or less transverse in direction. In the formatio reticularis of the anterior region, there is an almost entire absence of nerve-cells, and hence this part is known as the *substantia reticularis alba*; whereas in the lateral region nerve-cells are numerous, and as a consequence the formatio presents a grey appearance, and is termed the *substantia reticularis grisea*.

In the substance of the formatio reticularis are two small nuclei of grey matter: one, the *nucleus of Roller*, near the ventral surface of the hypoglossal nucleus; the other, the *nucleus lateralis*, between the olive and the spinal tract of the trigeminal nerve.

In the *substantia reticularis alba* the longitudinal fibres form two well-defined fasciculi, viz.: (1) the *lemniscus*, which lies close to the raphe, immediately behind the fibres of the pyramid; and (2) the *medial longitudinal fasciculus*, which is continued upwards from the anterior and lateral proper fasciculi of the medulla spinalis, and in the upper part of the medulla oblongata lies between the lemniscus and the grey substance of the rhomboid fossa. The longitudinal fibres in the *substantia reticularis grisea* are derived from fasciculi of the lateral funiculus of the medulla spinalis with the exception of the lateral

cerebrospinal fasciculus, which has passed over to the anterior region of the opposite side, and the direct cerebellar fasciculus which has entered the restiform body. They form indeterminate fibres, with the exception of a bundle named the *fasciculus solitarius*, which consists of descending fibres of the vagus and glossopharyngeal nerves. The transverse fibres of the formatio reticularis are the arcuate fibres already described (pp. 767, 769).

FIG. 744.—The formatio reticularis of the medulla oblongata, shown in a transverse section passing through the middle of the olive. (Testut.)



1. Anterior median fissure. 2. Fourth ventricle. 3. Formatio reticularis, with 3', its internal part (reticularis alba), and 3'', its external part (reticularis grisea). 4. Raphe. 5. Pyramid. 6. Lemniscus. 7. Inferior olivary nucleus, with the two accessory olivary nuclei. 8. Hypoglossal nerve, with 8', its nucleus of origin. 9. Vagus nerve, with 9', its nucleus of termination. 10. Medial vestibular nucleus. 11. Nucleus ambiguus (nucleus of origin of motor fibres of glossopharyngeal, vagus, and cerebral portion of accessory). 12. Nucleus gracilis. 13. Nucleus cuneatus. 14. Nucleus of trigeminal nerve, with 14', the spinal root of trigeminal nerve. 15. Fasciculus solitarius. 16. External arcuate fibres, with 16', the nucleus arcatus. 17. Nucleus lateralis. 19. Ligula.

Applied Anatomy.—In *bulbar paralysis*, i.e. paralysis of the medulla oblongata, which is really a special form of a progressive degeneration affecting the whole efferent or motor tract, the disease begins with impairment of the movements of the lips, tongue, pharynx, and larynx, due to degeneration of the motor cells in the nuclei of the medulla oblongata. Speech and swallowing become difficult, and the saliva dribbles from the open mouth. Other groups of muscles soon become involved, and death often occurs from 'aspiration pneumonia,' set up by food that has accidentally passed down the trachea.

THE PONS

The **pons** (pons Varolii) or fore part of the rhombencephalon is situated in front of the cerebellum. From its superior surface the cerebral peduncles emerge, one on either side of the middle line. Curving round each peduncle, close to the upper surface of the pons, a thin white band, the *tænia pontis*, is frequently seen; it enters the cerebellum between the brachium pontis and brachium conjunctivum. Behind and below, the pons is continuous with the medulla oblongata, but is separated from it in front and laterally by a transverse furrow in which the abducent, facial, and acoustic nerves appear.

Its *ventral* or *anterior surface* is prominent, markedly convex from side to side, less so from above downwards. It consists of transverse fibres arched like a bridge across the middle line, and gathered on either side into a compact mass which forms the brachium pontis. It rests upon the clivus of the sphenoidal bone, and is limited above and below by well-defined borders. In the

middle line is the shallow *sulcus basilaris* for the lodgment of the basilar artery ; this sulcus is bounded on either side by an eminence caused by the descent of the cerebrospinal fibres through the substance of the pons. Lateral to these eminences, near the upper border of the pons, the trigeminal nerves make their exit, each consisting of a smaller, medial, motor root, and a larger, lateral, sensory root ; vertical lines drawn immediately lateral to the attachments of the trigeminal nerves, may be taken as the boundaries between the ventral surface of the pons and the brachia pontis.

Its *dorsal or posterior surface*, triangular in shape, is hidden by the cerebellum, and is bounded laterally by the brachia conjunctiva ; it forms the upper part of the rhomboid fossa, with which it will be described.

Structure (fig. 745).—Transverse sections through the pons show it to be composed of two parts ; a ventral or basilar portion consisting for the most part of fibres arranged in transverse and longitudinal bundles, together with a small amount of grey substance ; and a dorsal or tegmental portion continuous with the reticular formation of the medulla oblongata, and most of the constituents of which are prolonged into the tegmenta of the cerebral peduncles.

The **basilar part** of the pons consists of : (a) superficial and deep transverse fibres, (b) longitudinal fasciculi, and (c) some small nuclei of grey substance termed the nuclei pontis.

The *superficial transverse fibres* constitute a rather thick layer on the ventral surface of the pons, and are collected into a large rounded bundle on either side. This bundle, with the addition of some transverse fibres from the deeper portion of the pons, forms the greater part of the brachium pontis.

The *deep transverse fibres* partly intersect and partly lie on the dorsal aspect of the longitudinal fasciculi. They course to the lateral border of the pons, and form part of the brachium pontis ; the further connexions of this brachium will be discussed with the anatomy of the cerebellum.

The *longitudinal fasciculi* are continued from the cerebral peduncles, and enter the upper surface of the pons. They stream downwards on either side of the middle line in bundles, separated from one another by the deep transverse fibres, and give rise to the eminences on the anterior surface. Some of these fibres end in the nuclei pontis, and others, after decussating, in the motor nuclei of the trigeminal, abducent, facial, and hypoglossal nerves ; but most of them are carried through the pons, and at its lower surface are collected into the pyramids of the medulla. The fibres which end in the motor nuclei of the cerebral nerves are derived from the pyramidal cells of the cerebral cortex, and bear the same relation to the motor cells of the cerebral nerves as the cerebrospinal fibres bear to the motor cells in the anterior column of the medulla spinalis.

The *nuclei pontis* are serially continuous with the arcuate nuclei in the medulla, and consist of small groups of multipolar nerve-cells which are scattered between the bundles of transverse fibres.

The *dorsal or tegmental part* of the pons is chiefly composed of an upward continuation of the reticular formation and grey substance of the medulla oblongata ; it is divided by a median raphe. It consists of transverse and longitudinal fibres and contains important grey nuclei. In the lower part of the pons the transverse fibres of the tegmental part are collected into a strand, named the *trapezoid body*. This consists of fibres which arise from the cells of the ventral or accessory cochlear nucleus, and will be referred to in connexion with the cochlear division of the acoustic nerve. In the substance of the trapezoid body is a collection of nerve-cells, termed the *trapezoid nucleus*. The longitudinal fibres are continuous with those of the medulla oblongata, and are mostly collected into two fasciculi on either side. One of these lies between the trapezoid body and the reticular formation, and is the upward prolongation of the *lemniscus* ; the second is situated near the floor of the fourth ventricle, and is the *medial longitudinal fasciculus*. Other longitudinal fibres, more diffusely distributed, arise from the cells of the grey substance of the pons.

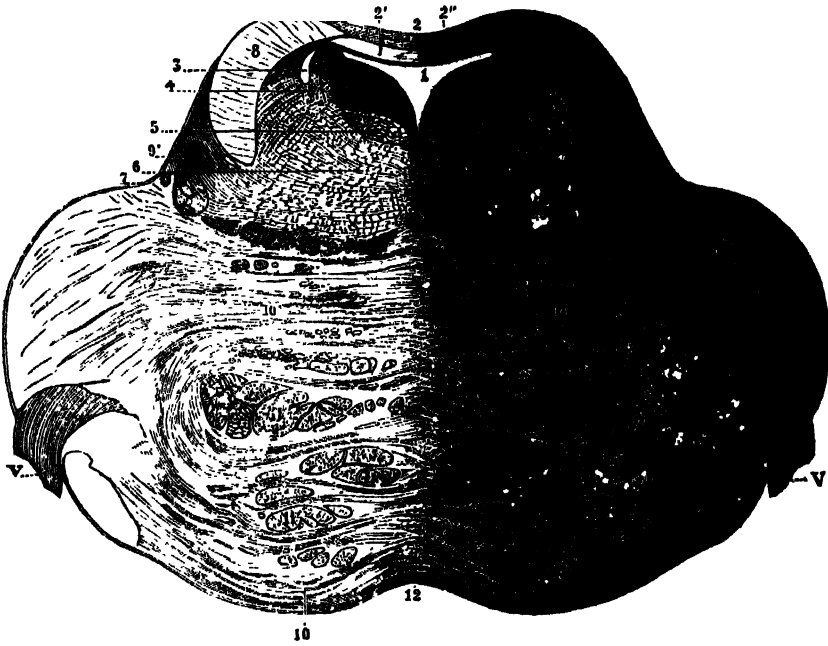
The rest of the dorsal part of the pons is a continuation upwards of the formatio reticularis of the medulla oblongata, and, like it, presents the appearance of a network, in the meshes of which are numerous nerve-cells. Besides these scattered nerve-cells, there are some larger masses of grey substance,

viz. the superior olivary nucleus and the nuclei of the trigeminal, abducent, facial, and acoustic nerves (fig. 740).

1. The *superior olivary nucleus* is a small mass of grey substance situated on the dorsal surface of the lateral part of the trapezoid body. Rudimentary in man, but well developed in certain animals, it exhibits the same structure as the inferior olivary nucleus, and is situated immediately above it. Some of the fibres of the trapezoid body end by arborising around the cells of this nucleus, while others arise from these cells.

2. The *nuclei of the trigeminal nerve* in the pons are two in number : a motor and a sensory. The *motor nucleus* is situated in the upper part of the pons, close to its posterior surface and along the line of the lateral margin of the fourth ventricle. The axons of its cells form a portion of the motor root of

FIG. 745.—Coronal section of the pons, at its upper part. (Testut.)



1. Fourth ventricle ; its ependyma is coloured yellow. 2. Anterior medullary velum, with 2', its white stratum, and 2'', its grey stratum. 3. Mesencephalic root of trigeminal nerve. 4. Nerve-cells associated with this root. 5. Medial longitudinal fasciculus. 6. Formatio reticularis. 7. Lateral sulcus. 8. Section of brachium conjunctivum. 9. Medial lemniscus. 9'. Lateral lemniscus. 10, 10. Transverse fibres of pons. 11, 11. Cerebrospinal fasciculi. 12. Raphe. V. Trigeminal nerve.

the trigeminal nerve : the remaining fibres of the motor root of this nerve consist of a fasciculus which arises from the grey substance of the floor of the cerebral aqueduct, and hence is named the *mesencephalic root*. The *sensory nucleus* is lateral to the motor one, and beneath the brachium conjunctivum. Some of the sensory fibres of the trigeminal nerve end in this nucleus ; but the greater number descend, under the name of the spinal tract of the trigeminal nerve, to end in a nucleus which is continuous below with the substantia gelatinosa of Rolando. The motor and sensory roots of the trigeminal nerve pass through the substance of the pons and emerge near the upper margin of its anterior surface.

3. The *nucleus of the abducent nerve* is a spherical mass of grey substance situated close to the floor of the fourth ventricle, above the striæ medullares and subjacent to the medial eminence : it lies a little lateral to the ascending part of the facial nerve. The fibres of the abducent nerve pass forward through the entire thickness of the pons on the medial side of the superior olivary nucleus and between the lateral fasciculi of the cerebrospinal fibres, and emerge in the furrow between the lower border of the pons and the pyramid of the medulla oblongata.

4. The *nucleus of the facial nerve* is situated deeply in the reticular formation of the pons on the dorsal aspect of the superior olivary nucleus, and the roots of the nerve derived from it pursue a remarkably tortuous course in the substance of the pons. At first they pass backwards and medialwards until they reach the rhomboid fossa, close to the median sulcus, where they are collected into a round bundle; this bundle passes upwards and forwards, producing an elevation, the *colliculus facialis*, in the rhomboid fossa, and taking a sharp bend round the nucleus of the abducent nerve, arches lateralwards through the substance of the pons to emerge at its lower border in the interval between the olive and the restiform body of the medulla oblongata.

5. The *nuclei of the acoustic nerve*.—The acoustic nerve consists of a cochlear and a vestibular nerve. The fibres of the cochlear nerve end in two nuclei: (a) the *lateral cochlear nucleus*, on the dorsolateral surface of the restiform body; and (b) the *ventral or accessory cochlear nucleus*, on the ventral aspect of the restiform body. The nuclei in which the vestibular nerve ends are (a) the *medial or chief vestibular nucleus*, corresponding to the lower part of the area acustica in the rhomboid fossa; the caudal end of this nucleus is termed (b) the *descending or spinal vestibular nucleus*; (c) the *lateral vestibular nucleus* (nucleus of Deiters), consisting of large multipolar cells and situated in the lateral angle of the rhomboid fossa; the dorsolateral part of this nucleus is sometimes termed (d) the *superior vestibular nucleus* (nucleus of Bechterew).

Applied Anatomy.—Injury to the pons, such as may occur on the occlusion or rupture of one of its blood-vessels, often gives rise to a special train of symptoms that is almost diagnostic. Pontine lesions are characterised mainly by 'alternate paralyses'; that is to say, by paralysis of one of the motor cerebral nerves on one side, and of the limbs on the other side of the body. Thus a hæmorrhage into the lower part of the pons might cause paralysis of the face ('lower segment paralysis') on the same side, from destruction of the facial nucleus or nerve-root, and paralysis of the arm and leg on the opposite side from injury to the adjacent cerebrospinal tract. In the same way, paralysis of the Rectus lateralis of one eye and of the Rectus medialis of the other ('conjugate paralysis' of the muscles turning the two eyes in one direction) and often paralysis of one side of the face as well, together with palsy of the limbs on the opposite side of the body, may be found when the lesion occurs about the nucleus of the abducent nerve. Hearing is often unaffected in pontine lesions, possibly because the central acoustic tract occupies a ventral and lateral position in the pons.

THE CEREBELLUM

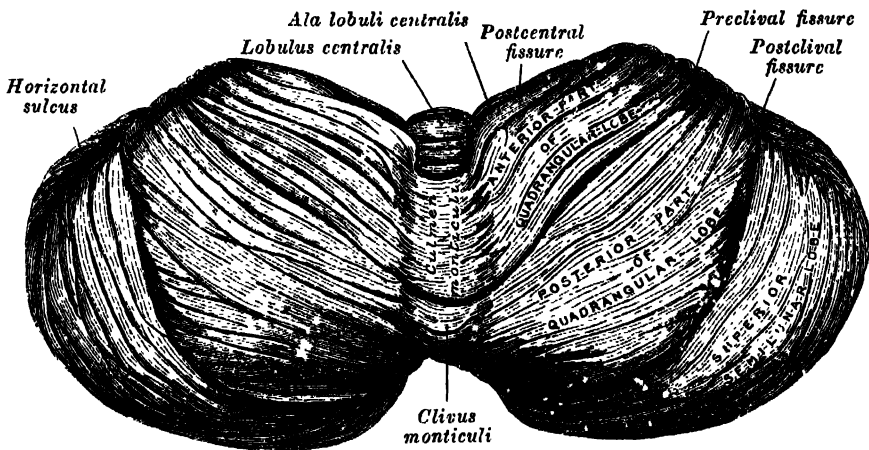
The cerebellum constitutes the largest part of the hind-brain. It lies behind the pons and medulla oblongata; between its central portion and these structures is the cavity of the fourth ventricle. It rests on the inferior fossæ of the occipital bone and is covered by the tentorium cerebelli, a fold of dura mater which separates it from the tentorial surface of the cerebrum. It is somewhat ovoid in form, but constricted medially and flattened from above downwards, its greatest diameter being from side to side. Its surface is not convoluted like that of the cerebrum, but is traversed by numerous curved furrows or sulci, which vary in depth at different parts, and separate the laminae of which it is composed. Its average weight in the male is about 150 gms. In the adult the proportion between the cerebellum and cerebrum is about 1 to 8, in the infant about 1 to 20.

Lobes of the cerebellum.—The cerebellum consists of a median and two lateral parts. The median portion is constricted, and is called the *vermis*, from the annulated appearance of its surface; the lateral expanded portions are named the *hemispheres*. On the upper surface of the cerebellum the vermis is elevated above the level of the hemispheres, but on the under surface it is sunk almost out of sight in a deep depression between them; this depression is called the *vallecula cerebelli*, and lodges the posterior part of the medulla oblongata. The part of the vermis on the upper surface of the cerebellum is named the *superior vermis*; that on the lower surface, the *inferior vermis*. The hemispheres are separated below and behind by a deep notch, the *posterior cerebellar notch*, and in front by a broader, shallower notch, the *anterior cerebellar notch*. The posterior notch contains the upper part of the falx cerebelli, a fold

of dura mater. The anterior notch lies close to the pons and upper part of the medulla, and its superior edge encircles the inferior colliculi and the brachia conjunctiva cerebelli.

The cerebellum is characterised by its laminated or foliated appearance ; it is marked by curved fissures, which extend for a considerable distance into its substance, and divide it into a series of layers or folia. The largest and deepest fissure is named the *horizontal sulcus*. It commences in front at the pons, and passes horizontally round the free margin of the hemisphere to the middle line behind : it divides the cerebellum into an upper and a lower portion. Several secondary but deep fissures separate the cerebellum into lobes, and these are further subdivided by shallower sulci, which separate the individual folia or laminae from each other. Sections across the laminae show that the folia, though differing in appearance from the convolutions of the cerebrum, are analogous to them, inasmuch as they consist of central white substance covered by grey substance.

FIG. 746.—The superior surface of the cerebellum. (Schäfer.)



The cerebellum is connected to the cerebrum by the brachia conjunctiva, to the pons by the brachia pontis, and to the medulla oblongata by the restiform bodies.

The superior surface of the cerebellum (fig. 746) is elevated in the middle and sloped towards the circumference, the hemispheres being connected together by the superior vermis, which assumes the form of a raised median ridge, most prominent in front, but not sharply defined from the hemispheres.

The superior vermis is subdivided from before backwards into the lingula, the lobulus centralis, the monticulus and the folium vermis, and each of these, with the exception of the lingula, is continuous with corresponding parts of the hemispheres—the lobulus centralis with the alæ, the monticulus with the quadrangular lobules, and the folium vermis with the superior semilunar lobules.

The **lingula** is a small tongue-shaped process, consisting of four or five folia ; it lies in front of and is concealed by the lobulus centralis. It rests on the dorsal surface of the anterior medullary velum, and its white substance is continuous with that of the velum.

The **lobulus centralis and alæ**.—The lobulus centralis is a small square lobule, situated in the anterior cerebellar notch. It overlaps the lingula, but is separated from it by the *precentral fissure* ; laterally, it is continued into each hemisphere, as a wing-like prolongation, the *ala lobuli centralis*.

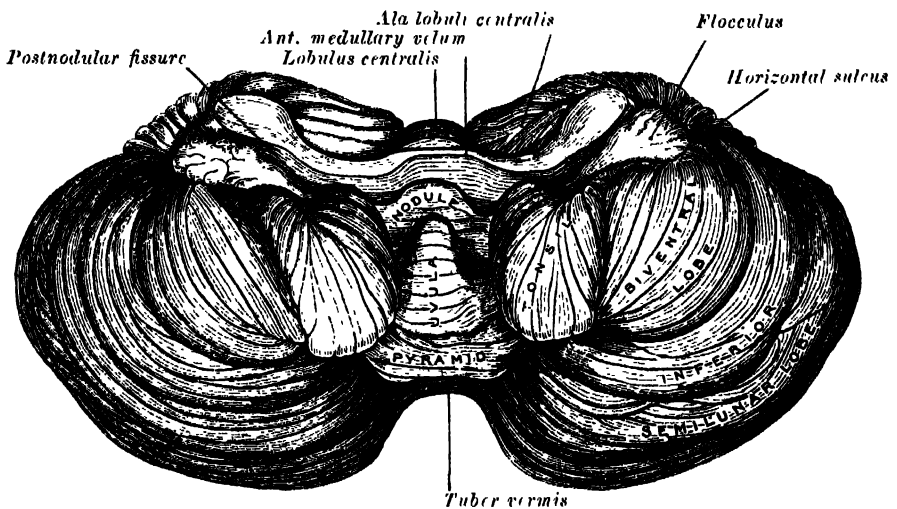
The **monticulus and quadrangular lobules**.—The monticulus is the largest part of the superior vermis. Anteriorly, it overlaps the lobulus centralis from which it is separated by the *postcentral fissure* ; laterally, it is continuous with the *quadrangular lobules* in the hemispheres. It is divided by the *preclival*

fissure into an anterior, raised part, the *culmen* or summit, and a posterior sloped part, the *clivus*; the quadrangular lobule is similarly divided. The culmen and the anterior parts of the quadrangular lobules form the *lobus culminis*; the clivus and the posterior parts, the *lobus clivi*.

The folium vermis and superior semilunar lobules.—The folium vermis (*folium caquininis*) is a short, narrow, concealed band at the posterior extremity of the superior vermis, consisting apparently of a single folium, but in reality marked on its upper and under surfaces by secondary fissures. Laterally, it expands in either hemisphere into a considerable lobule, the *superior semilunar lobule*, which occupies the posterior third of the upper surface of the hemisphere, and is bounded below by the *horizontal sulcus*. The folium vermis and the superior semilunar lobules form the *lobus semilunaris*.

The inferior surface of the cerebellum (fig. 747) presents, in the middle line, the *inferior vermis*, buried in the vallecule, and separated from the hemisphere on either side by a deep groove, the *sulcus vallecule*. This surface,

FIG. 747.—The inferior surface of the cerebellum. (Schäfer.)



like the superior, is divided into lobules; but the arrangement is more complicated, and the relations of the parts of the vermis to those of the hemispheres are less clearly marked. The inferior vermis is subdivided from before backwards, into: (1) the *nodule*, (2) the *uvula*, (3) the *pyramid*, and (4) the *tuber vermis*; the corresponding parts in the hemispheres are: (1) the *flocculus*, (2) the *tonsilla cerebelli*, (3) the *biventral lobule*, and (4) the *inferior semilunar lobule*. The three main fissures are: (1) the *postnodular fissure*, which runs transversely across the vermis, between the nodule and the uvula; in the hemispheres this fissure passes in front of the tonsilla and the biventral lobe but behind the flocculus, and joins the anterior end of the horizontal sulcus. (2) The *prepyramidal fissure* crosses the vermis between the uvula and the pyramid, then curves forwards between the tonsilla and the biventral lobe, to join the postnodular fissure. (3) The *postpyramidal fissure* passes across the vermis between the pyramid and the tuber vermis, and, in the hemisphere, courses behind the tonsilla and biventral lobule, and then along the lateral border of the biventral lobule to the postnodular sulcus; in the hemisphere it forms the anterior boundary of the inferior semilunar lobule.

The nodule, posterior medullary velum and flocculus.—The nodule, or anterior end of the inferior vermis, abuts against the roof of the fourth ventricle, and can only be distinctly seen after the cerebellum has been separated from the medulla oblongata and pons. On either side of the nodule is a thin layer of white substance, named the *posterior medullary velum*. It is semilunar in form, its convex border being continuous with the white substance

of the cerebellum; it extends on either side as far as the flocculus. The flocculus is a prominent, irregular lobule, situated in front of the biventral lobule, between it and the brachium pontis cerebelli. It is subdivided into a few small laminæ, and is connected to the posterior medullary velum by its central white core. The flocculi, nodule, and posterior medullary velum constitute the *lobus noduli*.

The uvula and tonsillæ.—The uvula forms a considerable portion of the inferior vermis; it is separated on either side from the tonsilla by the *sulcus vallecule*, at the bottom of which it is connected to the tonsilla by a furrowed ridge of grey matter called the *furrowed band*. The tonsillæ are rounded masses, situated in the hemispheres. Each lies in a deep fossa, termed the *bird's nest* (*nidus avis*), between the uvula and the biventral lobule. The uvula and tonsillæ form the *lobus uvulæ*.

The pyramid and biventral lobules constitute the *lobus pyramidalis*. The pyramid, a conical projection, is the largest prominence of the inferior vermis. It is separated from the hemispheres by the *sulcus vallecule*, across which it is connected to the biventral lobule by an indistinct grey band, analogous to the furrowed band already described. The biventral lobule is somewhat ovoid in shape; its narrower end points backwards, and is joined by the grey band to the pyramid; its broader end, directed forwards, is on a line with the anterior border of the tonsilla, and is separated from the flocculus by the postnodular fissure. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure.

The tuber vermis and the inferior semilunar lobules form the *lobus tuberis*. The tuber vermis, the most posterior division of the inferior vermis, is of small size, and spreads out laterally into the large inferior semilunar lobules which comprise at least two-thirds of the inferior surface of the hemisphere.

INTERNAL STRUCTURE OF THE CEREBELLUM

The cerebellum consists of white and grey substance.

White substance.—If a sagittal section (fig. 748) be made through either hemisphere, the interior will be found to consist of a central stem of white substance, in the middle of which is a grey mass, the *dentate nucleus*. From this central white stem a series of plates is prolonged; these plates are covered with grey substance and form the laminæ. In consequence of the main branches from the central stem dividing and subdividing, a characteristic appearance, named the *arbor vitæ*, is presented. If the sagittal section be made through the middle of the vermis, it will be found that the central stem divides into a vertical and a horizontal branch. The vertical branch passes upwards to the culmen monticuli, where it subdivides freely, one of its ramifications passing forwards and upwards to the central lobule. The horizontal branch passes backwards to the folium vermis, greatly diminished in size in consequence of having given off large secondary branches: one, from its upper surface, ascends to the clivus monticuli; the others descend, and enter the tuber vermis, the pyramid, the uvula, and the nodule.

The white substance of the cerebellum includes two sets of nerve-fibres:

(1) *projection fibres*, (2) *fibræ propriæ*.

Projection fibres.—The cerebellum is connected to the other parts of the brain by three large bundles of projection fibres, viz. to the cerebrum by the brachia conjunctiva, to the pons by the brachia pontis, and to the medulla oblongata by the restiform bodies (fig. 749).

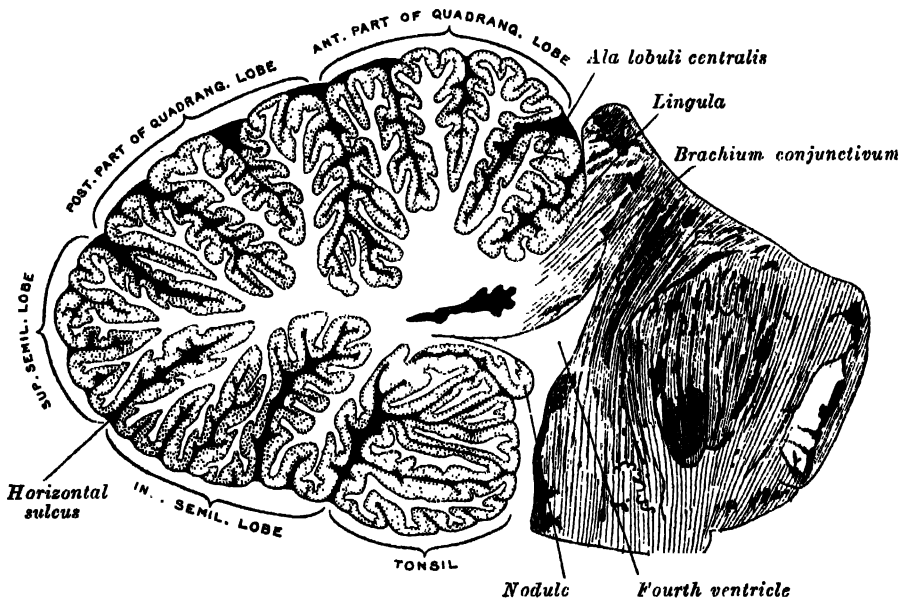
The brachia conjunctiva (superior cerebellar peduncles), two in number, emerge from the upper and medial part of the white substance of the hemispheres and are placed under cover of the upper part of the cerebellum. They are joined to each other across the middle line by the anterior medullary velum, and can be followed upwards as far as the inferior colliculi, under which they disappear. Below, they form the upper lateral boundaries of the fourth ventricle, but as they ascend they converge on the dorsal aspect of the ventricle and thus assist to roof it in.

The fibres of the brachium conjunctivum are mostly derived from the cells

of the dentate nucleus of the cerebellum, and emerge from the hilum of this nucleus; a few arise from the cells of the smaller grey nuclei in the cerebellar white substance, and some from the cells of the cerebellar cortex. They are continued upwards beneath the corpora quadrigemina, and the fibres of the two brachia undergo a complete decussation ventral to the cerebral aqueduct. Having crossed the middle line they divide into ascending and descending branches; the former end in the red nucleus, the thalamus, and the nucleus of the oculomotor nerve, while the latter can be traced as far as the dorsal part of the pons; Cajal believes them to be continued into the anterior funiculus of the medulla spinalis.

As already stated (p. 756), the majority of the fibres of the superficial anterolateral fasciculi of the medulla spinalis pass through the brachia conjunctiva on their way to the cerebellum.

FIG. 748.—A sagittal section of the left cerebellar hemisphere, near its junction with the vermis. (Schäfer.)



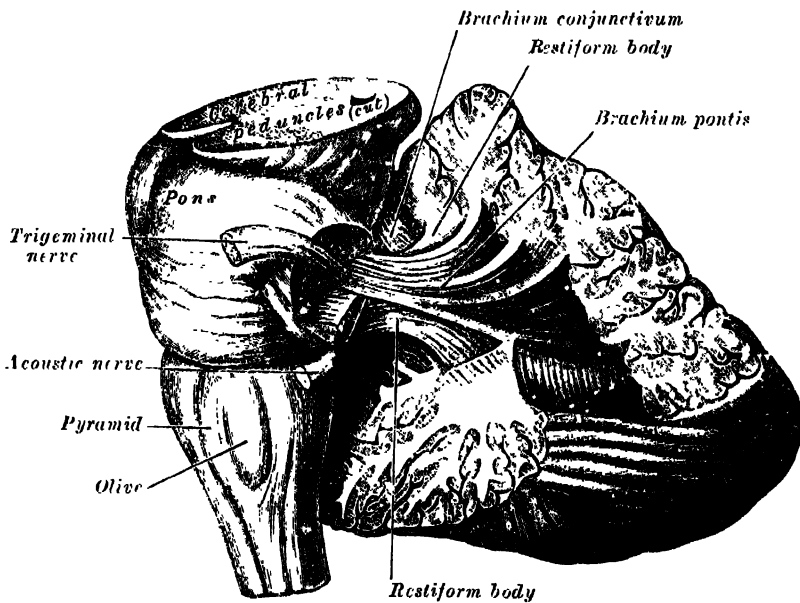
The brachia pontis (middle cerebellar peduncles) (fig. 749) are composed of centripetal fibres, which arise from the cells of the nuclei pontis of the opposite side and end in the cerebellar cortex; the fibres are arranged in three fasciculi, superior, inferior, and deep. The *superior* fasciculus is derived from the upper transverse fibres of the pons; it is directed backwards and lateralwards superficially to the other two fasciculi, and is distributed mainly to the lobules on the inferior surface of the cerebellar hemisphere, and to the parts of the superior surface adjoining the posterior and lateral margins. The *inferior* fasciculus is formed by the lowest transverse fibres of the pons; it passes under cover of the superior fasciculus and is continued downwards and backwards more or less parallel with it, to be distributed to the folia on the under surface close to the vermis. The *deep* fasciculus comprises most of the deep transverse fibres of the pons. It is at first covered by the superior and inferior fasciculi, but crossing obliquely it appears on the medial side of the superior, from which it receives a bundle; its fibres spread out and pass to the upper anterior cerebellar folia. The fibres of this fasciculus cover those of the restiform body.*

The restiform bodies (inferior cerebellar peduncles) pass at first upwards and lateralwards, forming part of the lateral walls of the fourth ventricle, and

* See article by E. B. Jamieson, *Journal of Anatomy and Physiology*, vol. xlii.

then bend abruptly backwards to enter the cerebellum between the brachia conjunctiva and brachia pontis. Each contains the following fasciculi: (1) the direct cerebellar tract of the medulla spinalis, which ends mainly in the superior vermis; (2) fibres from the nucleus gracilis and nucleus cuneatus, of the same and of the opposite sides; (3) fibres from the opposite inferior olivary nucleus; (4) crossed and uncrossed fibres from the reticular formation of the medulla oblongata; (5) vestibular fibres, derived partly from the vestibular division of the acoustic nerve and partly from the nuclei in which this division ends—these fibres occupy the medial segment of the restiform body and divide into ascending and descending branches; the ascending branches partly end in the roof nucleus of the opposite side of the cerebellum; (6) cerebellobulbar fibres which come from the opposite roof nucleus and probably from the dentate nucleus, and are said to end in the nucleus of Deiters and in the formatio reticularis of the medulla oblongata.

FIG. 749.—A dissection showing the projection fibres of the cerebellum.
(E. B. Janieson.)



The **anterior medullary velum** (valve of Vieussens) is a thin, transparent lamina of white substance, which stretches between the brachia conjunctiva; the folia of the lingula are prolonged on to the dorsal surface of its lower half. It forms, together with the brachia conjunctiva, the roof of the upper part of the fourth ventricle; it is narrow above, where it passes beneath the inferior colliculi, and broader below, where it is continuous with the white substance of the superior vermis. A median ridge, the *frenulum veli*, descends upon its upper part from between the inferior colliculi, and on either side of the frenulum the trochlear nerve emerges.

The **posterior medullary velum** is a thin layer of white substance, above and on either side of the nodule; it forms a part of the roof of the fourth ventricle. Somewhat semilunar in shape, its convex edge is continuous with the white substance of the cerebellum, while its thin concave margin is apparently free; in reality, however, it is continuous with the epithelium of the ventricle, which is prolonged downwards from the posterior medullary velum to the tæniæ of the fourth ventricle.

The two medullary vela are in contact with each other along their line of emergence from the white substance of the cerebellum; and this line of contact forms the *fastigium* or summit of the roof of the fourth ventricle, which, in a sagittal section through the cavity, appears as a pointed angle.

The *fibræ propriæ* of the cerebellum are of two kinds: (1) *commissural fibres*, which cross the middle line at the anterior and posterior parts of the vermis and connect the opposite halves of the cerebellum; (2) *arcuate or association fibres*, which connect adjacent lobules and laminæ with each other.

Grey substance.—The grey substance of the cerebellum is found in two situations: (1) on the surface, forming the cortex; (2) as independent masses in the interior.

(1) The **grey substance of the cortex** presents a characteristic foliated appearance, due to the series of laminæ which project from the central white substance; these in their turn give off secondary laminæ, which are covered by grey substance. Externally the cortex is covered by pia mater; internally it rests on the white substance.

Microscopic appearance of the cortex (fig. 750).—The cortex consists of two layers, viz. an external grey, or molecular, layer, and an internal rust-coloured, or nuclear, layer; between these is an incomplete stratum of cells, the *cells of Purkinje*.

The *external grey, or molecular, layer* consists of nerve-fibres and cells. The fibres comprise: (a) the dendrites and axon-collaterals of Purkinje's cells; (b) fibres from cells in the nuclear layer; (c) fibres from the central white substance of the cerebellum; (d) fibres derived from cells in the molecular layer itself. In addition to these are other fibres, which have a vertical direction and are the processes of large neuroglia cells situated in the nuclear layer. They pass outwards to the periphery of the grey substance, where they expand into little conical enlargements which form a sort of limiting membrane beneath the pia mater, analogous to the *membrana limitans interna* of the retina.

The *cells of the molecular layer* are small, and are arranged in an inner and an outer layer; they all possess branched axons. The cells of the inner layer are termed *basket-cells*; their axons run for some distance parallel with the surface of the folium and give off collaterals which form basket-like networks around the bodies of Purkinje's cells.

The *cells of Purkinje* are peculiar to the cerebellum; they form a single stratum of large, flask-shaped cells at the junction of the molecular and nuclear layers, their bases resting against the latter. The cells are flattened in a direction transverse to the long axis of the folium, and thus appear broad in sections carried across the folium, and fusiform in sections parallel to the long axis of the folium. From the neck of the flask one or more dendrites arise and pass into the molecular layer, where they subdivide and form an extremely rich arborescence, the various subdivisions of the dendrites being covered by lateral spine-like processes. This arborescence, like the cell, is flattened at right angles to the long axis of the folium; in other words, it resembles the branches of a fruit-tree trained against a trellis or a wall. Hence, in sections carried across the folium the arborescence is broad and expanded; whereas in sections parallel to the long axis of the folium, the arborescence, like the cell, is seen in profile, and is limited to a narrow area.

From the bottom of the flask-shaped cell the axon arises; this passes through the nuclear layer, and, becoming medullated, is continued as a nerve-fibre in the subjacent white substance. As it traverses the nuclear layer it gives off fine collaterals, some of which run into the molecular layer.

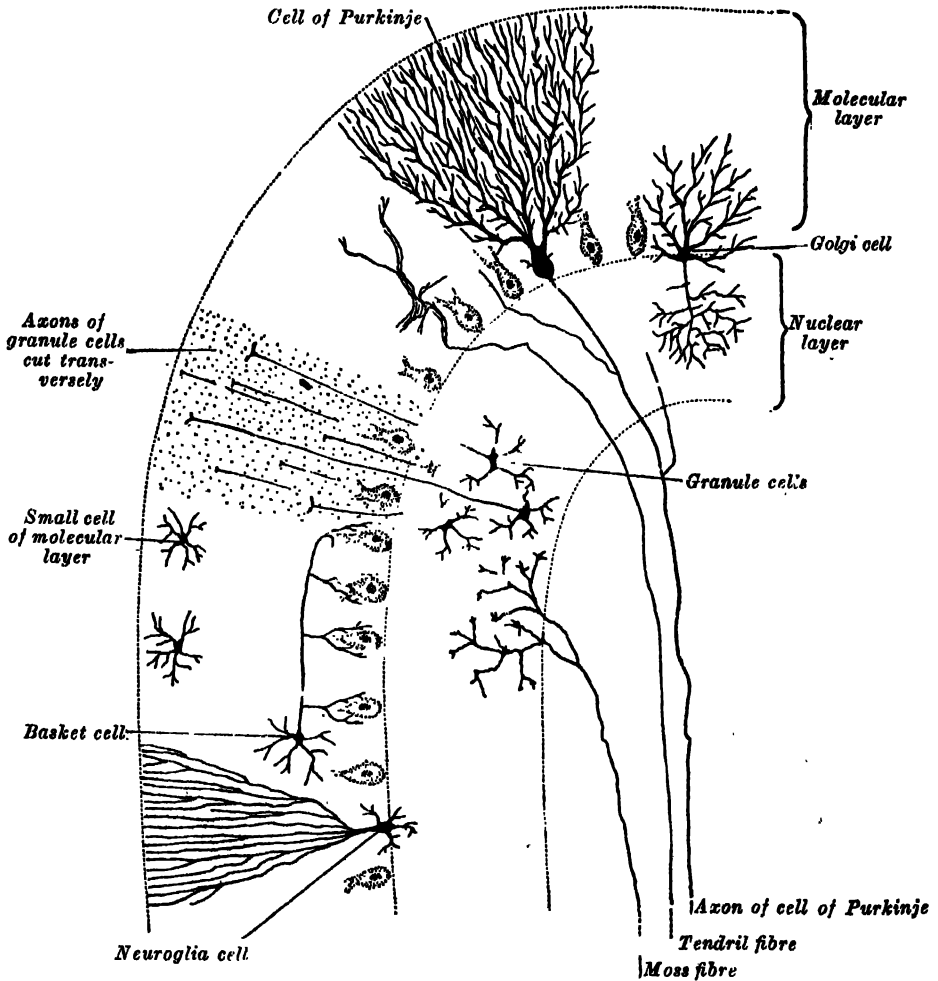
The *internal rust-coloured, or nuclear, layer* (fig. 750) contains numerous small nerve-cells of a reddish-brown colour, together with many nerve-fibrils. Most of the cells are nearly spherical and provided with short dendrites which spread out in a spider-like manner in the nuclear layer. Their axons pass into the molecular layer, and, bifurcating at right angles, run for some distance parallel to the long axis of the folium. In the outer part of the nuclear layer are some larger cells, of the type II. of Golgi. Their axons undergo frequent division as soon as they leave the nerve-cells, and pass into the nuclear layer; while their dendrites ramify chiefly in the molecular layer.

Finally, in the grey substance of the cerebellar cortex, there are fibres which come from the white centre and penetrate the cortex. The cell-origin of these fibres is unknown, but is probably in the grey substance of the medulla spinalis. Some of them end in the nuclear layer by dividing into numerous

branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the *moss-fibres*; they form an arborescence around the cells of the nuclear layer. Other fibres, the *clinging* or *tendrill fibres*, can be traced into the molecular layer, where their branches cling around the dendrites of Purkinje's cells.

(2) The independent centres of grey substance are imbedded in the white substance of the cerebellum, and are four in number on either side: one is of large size, and is known as the nucleus dentatus; the other three,

FIG. 750.—A transverse section of a cerebellar folium. (Diagrammatic, after Ramón y Cajal and Kölliker.)



much smaller, are situated near the middle of the cerebellum, and are known as the nucleus emboliformis, nucleus globosus, and nucleus fastigii.

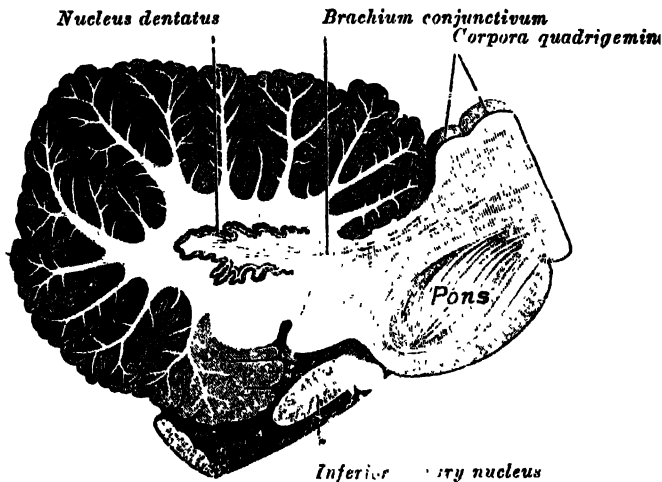
The *nucleus dentatus* (fig. 751) is situated a little to the medial side of the centre of the stem of the white substance of the hemisphere. It consists of an irregularly folded lamina, of a greyish-yellow colour, containing white fibres, and presenting on its anteromedial aspect an opening, the hilum, from which most of the fibres of the brachium conjunctivum emerge (p. 778).

The *nucleus emboliformis* lies close to the medial side of the nucleus dentatus, and partly covering its hilum. The *nucleus globosus*, an elongated mass, lies medially to the nucleus emboliformis, and is directed anteroposteriorly. The *nucleus fastigii* is somewhat larger than the other two, and is situated

close to the middle line at the anterior end of the superior vermis, and immediately over the roof of the fourth ventricle, from which it is separated by a thin layer of white substance.

Applied Anatomy.—The general functions of the cerebellum in the human appear to be the co-ordination of movements, and equilibration. The exact functions of its different parts are still quite uncertain, owing to the contradictory nature of the evidence furnished by (1) ablation experiments upon animals, and (2) clinical observations in man of the effects produced by abscesses or tumours affecting different portions of the organ. According to W. Aldren Turner, 'The following localising symptoms would therefore indicate the presence of a tumour implicating the right cerebellar hemisphere

FIG. 751.—A sagittal section through the right cerebellar hemisphere. The right olive has also been cut sagittally.



and middle peduncle: deafness in the right ear, associated with middle ear complications; and unsteady and uncertain gait with a tendency to fall more particularly to the right side; coarse nystagmoid oscillations on looking to the right; movements resembling those of disseminated sclerosis on voluntary effort of the right arm; an awkward uncertain action of the right leg; a slight increase of the right knee-jerk; and, perhaps, slight blunting of sensibility over the right cornea and side of the face.'

THE FOURTH VENTRICLE

The fourth ventricle, or cavity of the rhombencephalon, is situated in front of the cerebellum, and behind the pons and upper half of the medulla oblongata. Developmentally considered, it consists of three parts: a *superior* belonging to the isthmus rhombencephali, an *intermediate*, to the metencephalon, and an *inferior*, to the myelencephalon. It is lined by ciliated epithelium, and is continuous below with the central canal of the medulla oblongata*; above, it communicates, by means of a passage termed the cerebral aqueduct, with the cavity of the third ventricle. It presents four angles and possesses a roof or dorsal wall, a floor or ventral wall (rhomboid fossa), and lateral boundaries.

Angles.—The *superior angle* is on a level with the upper border of the pons, and is continuous with the lower end of the cerebral aqueduct. The *inferior angle* is on a level with the lower end of the olive, and opens into the central canal of the medulla oblongata. Each *lateral angle* corresponds with the point of meeting of the brachium conjunctivum and restiform body. A little

* J. T. Wilson (*Journal of Anatomy and Physiology*, vol. xl.) has pointed out that the central canal of the medulla oblongata, immediately below its entrance into the fourth ventricle, retains the cleft-like form presented by the canal in the fetal medulla spinalis, and that it is marked by dorsolateral and ventrolateral sulci.

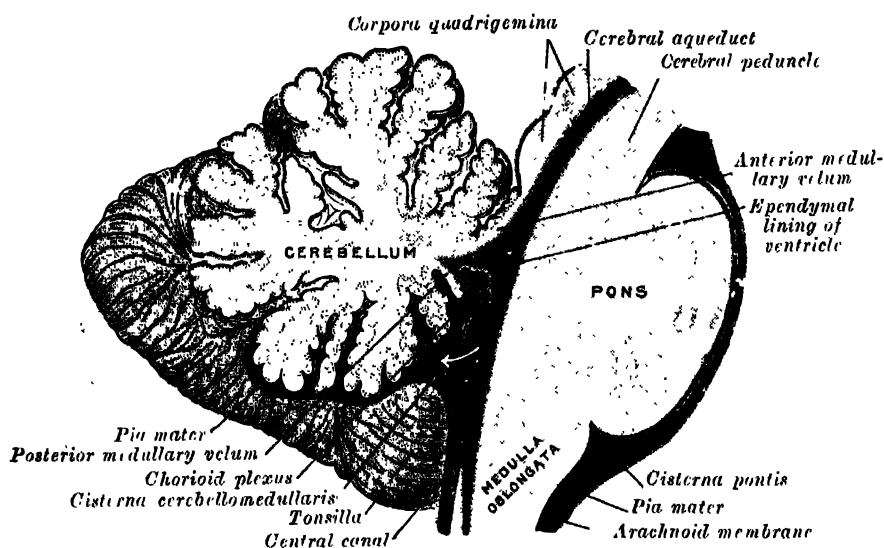
below the lateral angles, on a level with the *striae medullares*, the ventricular cavity is prolonged outwards in the form of two narrow *lateral recesses*, one on either side; these are situated between the restiform bodies and the cerebellopontine angle, and reach as far as the attachments of the glossopharyngeal and vagus nerves.

Lateral boundaries.—The lower part of each lateral boundary is constituted by the clava, the fasciculus cuneatus, and the restiform body; the upper part by the brachium pontis and the brachium conjunctivum.

Roof or dorsal wall (fig. 752).—The upper portion of the roof is formed by the brachia conjunctiva and the anterior medullary velum; the lower portion, by the posterior medullary velum, the epithelial lining of the ventricle covered by the tela chorioidea inferior, the tæniæ of the fourth ventricle, and the obex.

The *brachia conjunctiva* (p. 778), on emerging from the central white substance of the cerebellum, pass upwards and forwards, forming at first the

FIG. 752.—A scheme of the roof of the fourth ventricle. The arrow is in the foramen of Majendie.



lateral boundaries of the upper part of the ventricle; on approaching the inferior colliculi, they converge, and their medial portions overlap the ventricle and form part of its roof.

The *anterior medullary velum* (p. 780) fills in the angular interval between the brachia conjunctiva, and is continuous behind with the central white substance of the cerebellum; it is covered on its dorsal surface by the lingula of the superior vermis.

The *posterior medullary velum* (p. 780) is continued downwards and forwards from the central white substance of the cerebellum in front of the nodule and tonsillæ, and ends inferiorly in a thin, concave, somewhat ragged margin. Below this margin the roof of the ventricle is devoid of nervous matter except in the immediate vicinity of the lower lateral boundaries of the ventricle, where two narrow white bands, the *tæniæ of the fourth ventricle*, appear; these bands meet over the inferior angle of the ventricle in a thin triangular lamina, the *obex*. The non-nervous part of the roof is formed by the *epithelial lining of the ventricle*, which is prolonged downwards as a thin membrane, from the deep surface of the posterior medullary velum to the corresponding surface of the obex and tæniæ, and thence on to the floor of the ventricular cavity; it is covered and strengthened by a portion of the pia mater which is named the *tela chorioidea of the fourth ventricle*.

The *tæniæ of the fourth ventricle* (ligules) are two narrow bands of white matter, one on either side, which complete the lower part of the roof of the ventricle. Each consists of a vertical and a horizontal part. The vertical part is continuous with the clava, to which it is adherent by its lateral border. The horizontal portion extends transversely across the restiform body, below the stria medullares, and roofs in the lower and posterior part of the lateral recess; it is attached by its lower margin to the restiform body, and partly encloses the choroid plexus, which, however, projects beyond it like a cluster of grapes; and hence this part of the tænia has been termed the *cornucopia* (Bochdalek). The *obex* is a thin, triangular, grey lamina, which roofs in the lower angle of the ventricle and is attached by its lateral margins to the clavæ.* The *tela chorioidea of the fourth ventricle* is the name applied to the triangular fold of pia mater which is carried upwards between the cerebellum and the medulla oblongata. It consists of two layers, which are continuous with each other in front, and are more or less adherent throughout. The posterior layer covers the antero-inferior surface of the cerebellum, while the anterior is applied to the structures which form the lower part of the roof of the ventricle, and is continuous inferiorly with the pia mater on the restiform bodies and the closed part of the medulla.

Choroid plexuses.—Two highly vascular fringe-like processes of the tela chorioidea are named the choroid plexuses of the fourth ventricle; they invaginate the lower part of the roof of the ventricle and are everywhere covered by the epithelial lining of the cavity. Each consists of a vertical and a horizontal portion: the former lies close to the middle line, and the latter passes into the lateral recess and projects beyond its apex. The vertical parts of the plexuses are distinct from each other, but the horizontal portions are joined in the middle line; and hence the entire structure presents the form of the letter T, the vertical limb of which, however, is double.

Openings in the roof.—In the roof of the fourth ventricle there are three openings, a medial and two lateral: the medial aperture (*foramen Majendii*) is situated immediately above the inferior angle of the ventricle; the lateral apertures are found at the extremities of the lateral recesses. Through these openings the ventricular cavity communicates with the subarachnoid cavity, and the cerebrospinal fluid can circulate from the one cavity to the other.

Rhomboid fossa (fig. 753).—The anterior wall or floor of the fourth ventricle is named, from its shape, the rhomboid fossa; it is formed by the posterior surface of the pons and medulla oblongata. It is covered by a thin layer of grey substance continuous with that of the medulla spinalis; superficial to this is a thin lamina of neuroglia which constitutes the ependyma of the ventricle and supports a layer of ciliated epithelium. The fossa consists of three parts, superior, intermediate, and inferior. The *superior* part is triangular in shape and limited laterally by the brachia conjunctiva cerebelli; its apex, directed upwards, is continuous with the cerebral aqueduct; its base is represented by an imaginary line at the level of the upper ends of two small depressions, named the *superior foveæ*. The *intermediate* part extends from this level to that of the horizontal portions of the tæniæ of the ventricle; it is narrow above where it is limited laterally by the brachia pontis, but widens below and is prolonged into the lateral recesses of the ventricle. The *inferior* part is triangular, and its downwardly directed apex, named the *calamus scriptorius*, is continuous with the wall of the central canal of the closed part of the medulla oblongata.

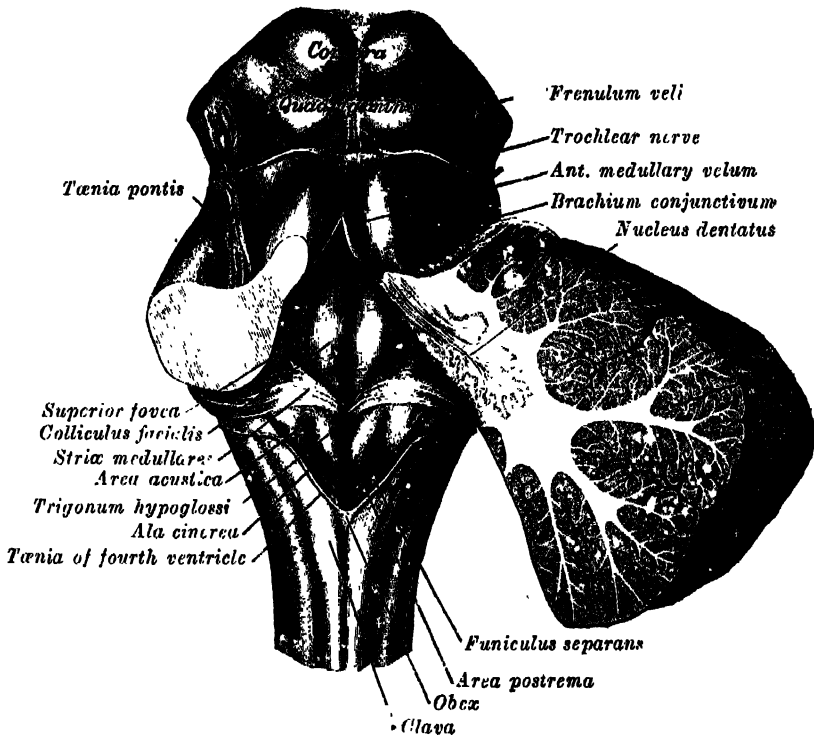
The rhomboid fossa is divided into symmetrical halves by a *median sulcus* which reaches from the upper to the lower angle of the fossa and is deeper below than above. On either side of this sulcus is an elevation, the *medial eminence*, bounded laterally by a sulcus, the *sulcus limitans*. In the superior part of the fossa the medial eminence has a width equal to that of the corresponding half of the fossa, but opposite the superior fovea it forms an elongated swelling, the *colliculus facialis*, which overlies the nucleus of the abducens

*J. T. Wilson, *loc. cit.*, recognises two forms of obex: (a) the *true obex*, constituted by a medullary thickening of the roof-plate, and (b) a *false or membranous obex* where the medullary thickening fails, and the roof-plate is represented only by the ependymal layer clothing the ventral surface of a pia reduplication which forms the main substance of the membranous fold in question.

nerve, and is in part produced by the ascending portion of the root of the facial nerve. In the inferior part of the fossa the medial eminence assumes the form of a triangular area, the *trigonum hypoglossi*. When examined under water with a lens the trigonum hypoglossi is seen to consist of a medial and a lateral area separated by a series of oblique furrows; the medial area corresponds with the upper part of the nucleus of the hypoglossal nerve, the lateral with a small nucleus, the *nucleus intercalatus*.

The *sulcus limitans* forms the lateral boundary of the medial eminence. Its superior part corresponds with the lateral limit of the fossa and presents a bluish-grey area, the *locus cæruleus*, which owes its colour to a patch of deeply

FIG. 753.—The rhomboid fossa.



pigmented nerve-cells, termed the *substantia ferruginea*. At the level of the colliculus facialis the sulcus limitans widens into a flattened depression, the *superior fovea*, and in the inferior part of the fossa appears as a distinct dimple, the *inferior fovea*. Lateral to the foveæ is a rounded elevation named the *area acustica* which extends into the lateral recess. Winding round the restiform body and crossing the area acustica and the medial eminence are a number of white strands, the *stria medullares* (*stria acusticæ*), which form a portion of the cochlear division of the acoustic nerve and disappear into the median sulcus. Below the inferior fovea, and between the trigonum hypoglossi and the lower part of the area acustica, is a triangular dark field, the *ala cinerea*, in which the sensory fibres of the vagus and glossopharyngeal nerves end. The lower end of the ala cinerea is crossed by a narrow translucent ridge, the *funiculus separans*, and between this funiculus and the clava is a small tongue-shaped area, the *area postrema*. On section it is seen that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, neuroglial tissue containing nerve-cells of moderate size.

THE MESENCEPHALON OR MID-BRAIN

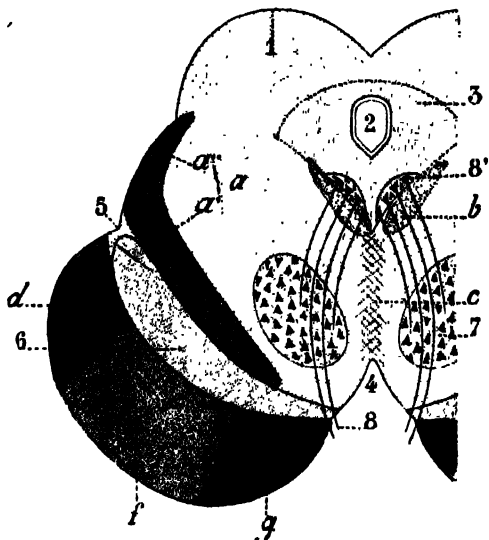
The mesencephalon or mid-brain is the short, constricted portion which connects the pons and cerebellum with the thalamencephalon and cerebral hemispheres. It is directed upwards and forwards, and consists of (1) a ventrolateral portion, composed of a pair of cylindrical bodies, named the *cerebral peduncles*; (2) a dorsal portion, consisting of four rounded eminences, named the *corpora quadrigemina*; and (3) an intervening passage or tunnel, the *cerebral aqueduct*, which represents the original cavity of the mid-brain and connects the third and fourth ventricles (fig. 754).

The cerebral peduncles (*crura cerebri*) are two cylindrical masses situated at the base of the brain, and largely hidden by the temporal lobes of the cerebrum, which must be drawn aside or removed in order to expose them. They emerge from the upper surface of the pons, one on either side of the middle line, and, diverging as they pass upwards and forwards, disappear into the substance of the cerebral hemispheres. The depressed area between the diverging cerebral peduncles is termed the *interpeduncular fossa*, and consists of a layer of greyish substance, the *posterior perforated substance*, which is pierced by small apertures for the transmission of blood-vessels. The lower part of the posterior perforated substance lies on the ventral aspect of the tegmenta, and contains a nucleus named the *interpeduncular ganglion* (p. 790); its upper part assists in forming the floor of the third ventricle.

The ventral surface of each peduncle is crossed behind, from the medial to the lateral side, by the superior cerebellar and posterior cerebral arteries, while, close to the point of disappearance of the peduncle into the cerebral hemisphere, the optic tract winds forwards around it. The medial surface of the peduncle forms the lateral boundary of the interpeduncular fossa, and is marked by a longitudinal furrow, the *oculomotor sulcus*, from which the roots of the oculomotor nerve emerge. The lateral surface of the peduncle is in relation to the gyrus hippocampi of the cerebral hemisphere and is crossed from behind forwards by the trochlear nerve. Running along it, is a longitudinal furrow, termed the *lateral sulcus*; the fibres of the lateral lemniscus come to the surface in this sulcus, and pass backwards and upwards, to disappear under the inferior colliculus.

Structure of the cerebral peduncles (figs. 755, 756).—On transverse section, each peduncle is seen to consist of a dorsal and a ventral part, separated by a deeply pigmented lamina of grey substance, termed the *substantia nigra*. The dorsal part is named the *tegmentum*; the ventral, the *base* or *crusta*. The bases of the peduncles are separated from each other, but the tegmenta are joined in the median plane by a forward prolongation of the raphe of the pons. Laterally, the tegmenta are free; dorsally, they blend with the *corpora quadrigemina*.

FIG. 754.—A transverse section through mid-brain. (Schematic.) (Testut.)



1. Corpora quadrigemina. 2. Cerebral aqueduct. 3. Central grey stratum. 4. Interpeduncular space. 5. Sulcus lateralis. 6. Substantia nigra. 7. Red nucleus of tegmentum. 8. Oculomotor nerve, with 8', its nucleus of origin. a. Lemniscus (in blue), with a' the medial lemniscus and a'' the lateral lemniscus. b. Medial longitudinal fasciculus. c. Raphe. d. Temporo-pontine fibres. e. Portion of medial lemniscus which runs to the lentiform nucleus and insula. f. Cerebropontine fibres. g. Fronto-pontine fibres.

NEUROLOGY

The base (*crusta* or *pes*) is semilunar on transverse section, and consists almost entirely of longitudinal bundles of efferent fibres which arise from the cells of the cerebral cortex and are grouped into three principal sets, viz. cerebrospinal, frontopontine, and temporopontine (fig. 754). The *cerebrospinal* fibres are derived from the cells of the motor area of the cerebral cortex and occupy the middle three-fifths of the base; some of them end in the nuclei

FIG. 755.—A transverse section of the mid-brain at the level of the inferior colliculi.

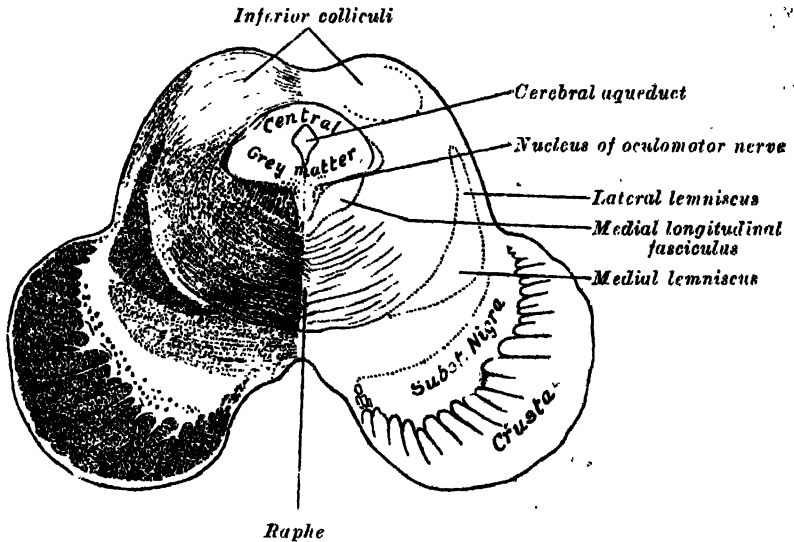
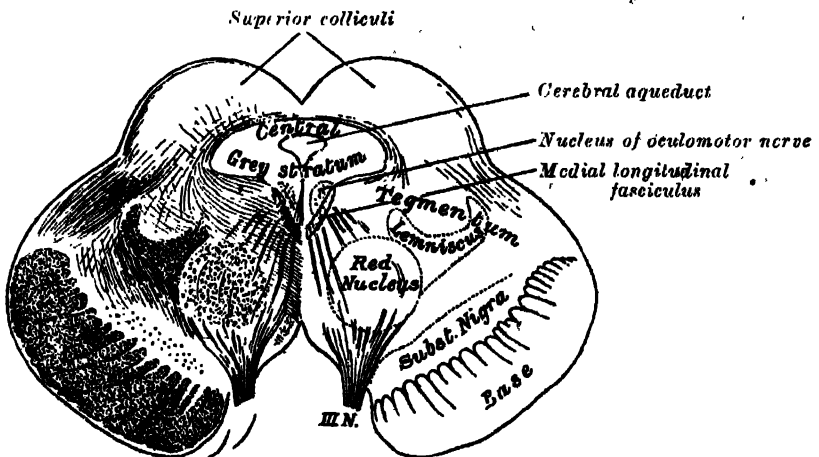


FIG. 756.—A transverse section of the mid-brain at the level of the superior colliculi.

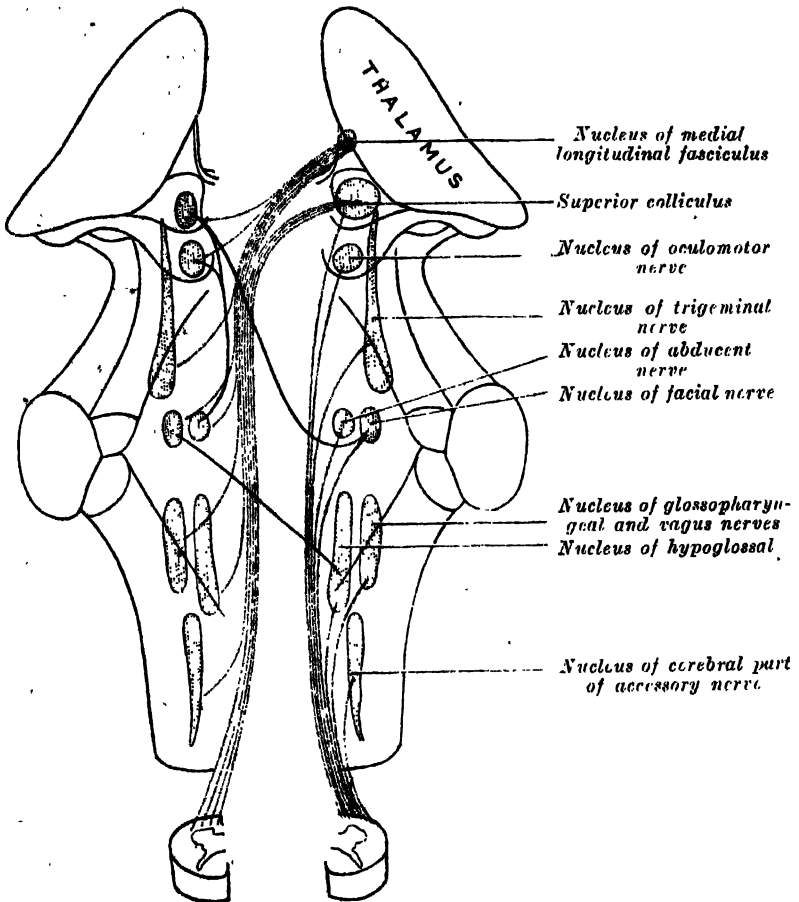


of the motor cerebral nerves of the opposite side, but most of them pass into the pyramids of the medulla oblongata. The *frontopontine* fibres are situated in the medial fifth of the base; they arise from the cells of the frontal lobe and end in the nuclei of the pons. The *temporopontine* fibres are lateral to the cerebrospinal fibres; they originate in the temporal lobe and end in the nuclei of the pons.*

* A band of fibres, the *tractus peduncularis transversus*, is sometimes seen emerging from in front of the superior colliculus; it passes round the ventral aspect of the peduncle about midway between the pons and the optic tract, and dips into the oculomotor sulcus. This band is a constant structure in many mammals, but is only present in about thirty per cent. of human brains. Since it undergoes atrophy after enucleation of the eyeballs, it may be considered as forming a path for visual sensations.

The *substantia nigra* is a layer of grey substance containing numerous deeply pigmented, multipolar nerve-cells. It is semilunar on transverse section, its concavity being directed towards the tegmentum; from its convexity, processes of it extend between the fibres of the base of the peduncle. Thicker medially than laterally, it reaches from the oculomotor sulcus to the lateral sulcus, and extends from the upper surface of the pons to the subthalamic region; its medial part is traversed by the fibres of the oculomotor nerve as these stream forwards to reach the oculomotor sulcus. The connexions of the cells of the *substantia nigra* have not been definitely established.

FIG. 757.—A scheme of the medial longitudinal fasciculus; motor fibres in red, sensory fibres in blue.



The *tegmentum* is continuous below with the reticular formation of the pons, and, like it, consists of a considerable amount of grey substance together with longitudinal and transverse fibres. The principal grey masses of the tegmentum are the red nucleus and the interpeduncular ganglion; of its fibres the chief longitudinal tracts are the brachium conjunctivum, the medial longitudinal fasciculus, and the lemniscus.

Grey substance.—The *red nucleus* is situated in the anterior part of the tegmentum, and is continued upwards into the posterior part of the subthalamic region. In sections at the level of the superior colliculus it appears as a circular mass which is traversed by the fibres of the oculomotor nerve. Most of the fibres of the brachium conjunctivum end in this nucleus (p. 778). The axons of its larger cells cross the middle line and are continued downwards into the lateral funiculus of the medulla spinalis as the rubrospinal tract (p. 755); those of its smaller cells end mainly in the thalamus.

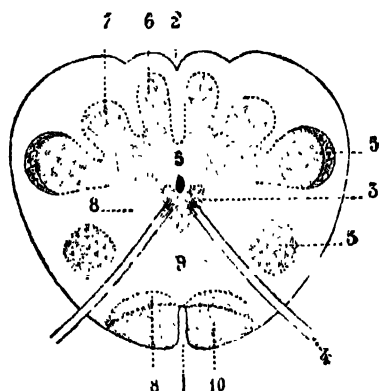
The *interpeduncular ganglion* is a median collection of nerve-cells situated in the ventral part of the tegmentum. The fibres of the fasciculus retroflexus of Meynert, which have their origin in the cells of the ganglion habenulæ (p. 797), end in the interpeduncular ganglion.

Besides the two nuclei mentioned, there are small collections of nerve-cells which form the dorsal and ventral nuclei and the central nucleus or nucleus of the raphe.

White substance.—(1) The origin and course of the *brachium conjunctivum* have already been described (p. 778).

(2) The *medial (posterior) longitudinal fasciculus* (fig. 757) is continuous below with the proper fasciculi of the anterior and lateral funiculi of the medulla spinalis; and has been traced by Edinger as far as a nucleus, the *nucleus of the*

FIG. 758.—Transverse section passing through the sensory decussation (decussation of the lemniscus). (Schematic.) (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3, 3'. Head and base of the anterior column (in red). 4. Hypoglossal nerve. 5. Bases of the posterior columns. 5'. Tuberculum cinereum (tubercle of Rolando). 6. Nucleus gracilis. 7. Nucleus cuneatus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Pyramid.

through the medial longitudinal fasciculus from the nucleus of the abducent nerve into the oculomotor nerve of the opposite side, and through this nerve to the Rectus medialis oculi. Fibres are said to be prolonged through this fasciculus from the nucleus of the oculomotor nerve into the facial nerve, and distributed to the Orbicularis oculi, the Corrugator, and the Frontalis.*

The fibres of the *lemniscus* or *fillet* (fig. 759) take origin in the nucleus gracilis and nucleus cuneatus of the medulla oblongata, and cross to the opposite side in the sensory decussation (p. 767). They then pass upwards through the medulla oblongata, in which they are situated behind the cerebrospinal fibres and between the olives. Here they are joined by the fibres of the superficial anterolateral fasciculus, these having already undergone decussation in the medulla spinalis. As the lemniscus ascends, it receives additional fibres from the terminal nuclei of the sensory cerebral nerves of the opposite side. In the pons, it assumes a flattened, ribbon-like appearance, and is placed dorsal to the trapezium. In the mesencephalon, its lateral part is folded backwards and forms nearly a right angle with its medial portion; and hence it is customary to speak of a lateral and a medial lemniscus.

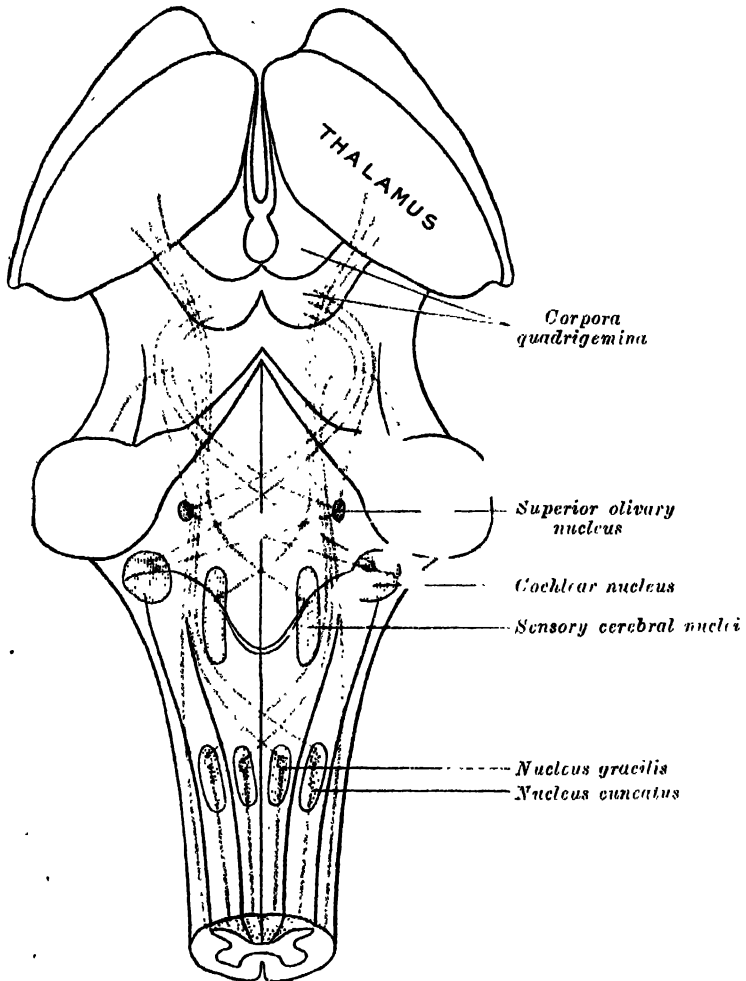
The *lateral lemniscus* comes to the surface in the lateral sulcus, and disappears under the inferior colliculus. It consists of fibres from the terminal nuclei of the cochlear division of the acoustic nerve, together with others from the superior olivary and trapezoid nuclei. Most of these fibres are crossed,

* Bruce and Pirie ('On the Origin of the Facial Nerve,' *Review of Neurology and Psychiatry*, vol. vi. No. 12, December 1908) produce weighty evidence against the view that the facial nerve derives fibres from the nucleus of the oculomotor nerve.

but some are uncrossed; they end in the inferior colliculus and the medial geniculate body.

The *medial lemniscus* begins in the nucleus gracilis and nucleus cuneatus of the opposite side, and is joined by the superficial anterolateral fasciculus of the medulla spinalis and by fibres from the terminal nuclei of the sensory cerebral nerves of the opposite side, excepting the cochlear division of the acoustic nerve. In the cerebral peduncle, a few of its fibres pass upwards in

FIG. 759.—A scheme showing the course of the fibres of the lemniscus; medial lemniscus in blue, lateral in red.



the lateral part of the base of the peduncle on the dorsal aspect of the temporo-pontine fibres, and reach the lentiform nucleus and the insula. With this exception the fibres of the medial lemniscus are prolonged through the tegmentum into the thalamus, around the cells of which they form arborisations. From the cells of the thalamus a relay of fibres is prolonged to the cerebral cortex.

In the tegmentum there are, besides these three tracts, the *tectospinal fasciculus* from the superior colliculus, and the *rubrospinal fasciculus* from the red nucleus; these cross the middle line and are continued downwards into the medulla spinalis (p. 755).

The *corpora quadrigemina* (fig. 763) are four rounded eminences which form the dorsal part of the mesencephalon. They are situated above and

in front of the anterior medullary velum and brachia conjunctiva, and below and behind the third ventricle and posterior commissure. They are covered by the splenium of the corpus callosum, and are partly overlapped on either side by the medial angle, or pulvinar, of the posterior end of the thalamus. The corpora quadrigemina are arranged in pairs (superior and inferior colliculi), and are separated from one another by a crucial sulcus. The longitudinal part of this sulcus expands superiorly to form a slight depression which supports the *pineal body*, a cone-like structure which projects backwards from the thalamencephalon and partly obscures the superior colliculi. From the inferior end of the longitudinal sulcus a white band, termed the *frenulum veli*, is prolonged downwards to the anterior medullary velum; on either side of this band the trochlear nerve emerges, and passes forwards on the lateral aspect of the cerebral peduncle to reach the base of the brain. The *superior colliculi* are larger and darker in colour than the inferior, and are oval in shape. The *inferior colliculi* are hemispherical, and somewhat more prominent than the superior. The superior colliculi are associated with the sense of sight, the inferior with that of hearing.

From the lateral aspect of each colliculus a white band, termed the *brachium*, is prolonged, upwards and forwards. The *superior brachium* extends laterally from the superior colliculus, and, passing between the pulvinar and medial geniculate body, is partly continued into an eminence called the lateral geniculate body, and partly into the optic tract. The *inferior brachium* passes forwards and upwards from the inferior colliculus and disappears under cover of the medial geniculate body.

In close relationship with the corpora quadrigemina are the brachia conjunctiva, which emerge from the upper and medial parts of the cerebellar hemispheres. They run upwards and forwards, and, passing under the inferior colliculi, enter the tegmenta as already described (p. 778).

Structure of the corpora quadrigemina.—The *inferior colliculus* consists of a compact nucleus of grey substance containing large and small multipolar nerve-cells, and is more or less completely surrounded by fibres derived from the lateral lemniscus; most of these fibres end in the grey nucleus of the same side, but some cross the middle line and end in that of the opposite side. From the cells of the grey nucleus, fibres are prolonged through the inferior brachium into the tegmentum of the cerebral peduncle, and are carried to the thalamus and the cortex of the temporal lobe; other fibres cross the middle line and end in the opposite colliculus.

The *superior colliculus* is covered by a thin stratum (*stratum zonale*) of white fibres, the majority of which are derived from the optic tract. Beneath this is the *stratum cinereum*, a cap-like layer of grey substance, thicker in the centre than at the circumference, and consisting of numerous small multipolar nerve-cells imbedded in a fine network of nerve-fibres. Still deeper is the *stratum opticum*, containing large multipolar nerve-cells separated by numerous fine nerve-fibres. Finally, there is the *stratum lemnisci*, consisting of fibres derived partly from the lemniscus and partly from the cells of the stratum opticum; interspersed among these fibres are many large multipolar nerve-cells. Of the afferent fibres which reach the superior colliculus, some are derived from the lemniscus, but the majority have their origins in the retina and are conveyed to the superior colliculus through the superior brachium; all of them end by arborising around the cells of the grey substance. Of the efferent fibres, some cross the middle line to the opposite colliculus; many ascend through the superior brachium, and finally reach the cortex of the occipital lobe of the cerebrum; while others, after undergoing decussation (*fountain decussation of Meynert*) form the tectospinal fasciculus which descends through the formatio reticularis of the mesencephalon, pons, and medulla oblongata into the medulla spinalis, where it is found partly in the anterior funiculus and partly intermingled with the fibres of the rubrospinal tract.

The corpora quadrigemina are larger in the lower animals than in man. In fishes, reptiles, and birds, they are hollow, and only two in number (corpora bigemina); they represent the superior colliculi of mammals, and are frequently termed the optic lobes, because of their intimate connexion with the optic tracts.

The **cerebral aqueduct** (**aqueduct of Sylvius**) is a narrow canal, about 15 mm. long, situated between the corpora quadrigemina and tegmenta, and connecting the third with the fourth ventricle. Its form, as seen in transverse sections, varies at different levels, being T-shaped below, triangular above, and oval in the middle; its central part is slightly dilated, and was named by Retzius the *ventricle of the mid-brain*. It is lined by ciliated columnar epithelium, and is surrounded by a layer of grey substance named the *central grey stratum*; this is continuous below with the grey substance in the rhomboid fossa, and above with that of the third ventricle. Dorsally, the aqueduct is partly separated from the grey substance of the quadrigeminal bodies by the fibres of the lemnisci; ventral to it are the medial longitudinal fasciculus, and the formatio reticularis of the tegmentum. Scattered throughout the central grey stratum are numerous nerve-cells of various sizes, interlaced by a network of fine fibres. Besides these scattered cells it contains three groups which constitute the nucleus of the mesencephalic root of the trigeminal nerve and the nuclei of the oculomotor and trochlear nerves. The *nucleus of the trigeminal nerve* extends along the entire length of the aqueduct, and occupies the lateral part of the grey stratum, while the nuclei of the oculomotor and trochlear nerves are situated in its ventral part. The *nucleus of the oculomotor nerve* is about 10 mm. long, and lies mainly under the superior colliculus, beyond which, however, it extends for a short distance into the grey substance of the third ventricle. The *nucleus of the trochlear nerve* is small and nearly circular, and is on a level with a plane carried transversely through the upper part of the inferior colliculus.

THE PROSENCEPHALON OR FORE-BRAIN

The **prosencephalon** or **fore-brain** consists of: (1) the *diencephalon*, corresponding in a large measure to the third ventricle and the structures which bound it; and (2) the *telencephalon*, comprising the largest part of the brain, viz. the cerebral hemispheres; these hemispheres are connected with each other across the middle line, and each contains a large cavity, named the lateral ventricle. The lateral ventricles communicate through the inter-ventricular foramen with the third ventricle, but are separated from each other by a median septum, the septum pellucidum; this contains a slit-like cavity, which does not communicate with the ventricles.

THE DIENCEPHALON

The **diencephalon** is connected above and in front with the cerebral hemispheres; behind with the mesencephalon. Its upper surface is concealed by the corpus callosum, and is covered by a fold of pia mater, named the tela chorioidea of the third ventricle; inferiorly it reaches to the base of the brain.

The diencephalon comprises: (1) the thalamencephalon; (2) the pars mamillaris hypothalami; and (3) the posterior part of the third ventricle. For descriptive purposes, however, it is more convenient to consider the whole of the third ventricle and its boundaries together: this necessitates the inclusion, under this heading, of the pars optica hypothalami and the corresponding part of the third ventricle—structures which properly belong to the telencephalon.

The **thalamencephalon** comprises: (1) the thalamus; (2) the metathalamus or corpora geniculata; and (3) the epithalamus, consisting of the trigonum habenulae, the pineal body, and the posterior commissure.

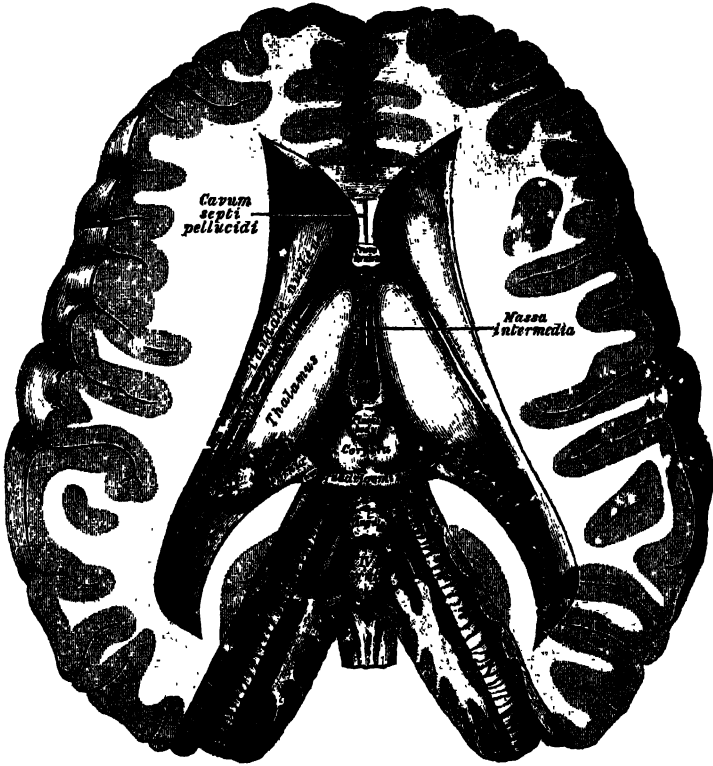
The **thalami** (figs. 760, 761) are two large ovoid masses, situated one on either side of the third ventricle and reaching for some distance behind that cavity. Each measures about 4 cm. in length, and presents two extremities, an anterior and a posterior, and four surfaces, superior, inferior, medial, and lateral.

The *anterior extremity* is narrow ; it lies close to the middle line and forms the posterior boundary of the interventricular foramen.

The *posterior extremity* is expanded, directed backwards and lateralwards, and overlaps the superior colliculus. Medially, this extremity presents an angular prominence, the *pulvinar*, which is continued laterally into an oval swelling, the *lateral geniculate body*, while beneath the pulvinar, but separated from it by the superior brachium, is a second oval swelling, the *medial geniculate body*.

The *superior surface* is free, slightly convex, and covered by a layer of white substance, termed the *stratum zonale*. It is separated laterally from the ventricular surface of the caudate nucleus by a white band, the *stria terminalis*, and by the terminal vein. It is divided into a medial and a lateral

FIG. 760.—A dissection showing the ventricles of the brain.



portion by an oblique shallow furrow which runs from behind forwards and medialwards and corresponds with the lateral margin of the fornix ; the lateral part forms a portion of the floor of the lateral ventricle, and is covered by the epithelial lining of this cavity ; the medial part is covered by the tela chorioidea of the third ventricle, and is destitute of an epithelial covering. In front, the superior is separated from the medial surface by a salient margin, the *tænia thalami*, along which the epithelial lining of the third ventricle is reflected on to the under surface of the tela chorioidea. Behind, it is limited medially by a groove, the *sulcus habenulae*, which intervenes between it and a small triangular area termed the *trigonum habenulae*.

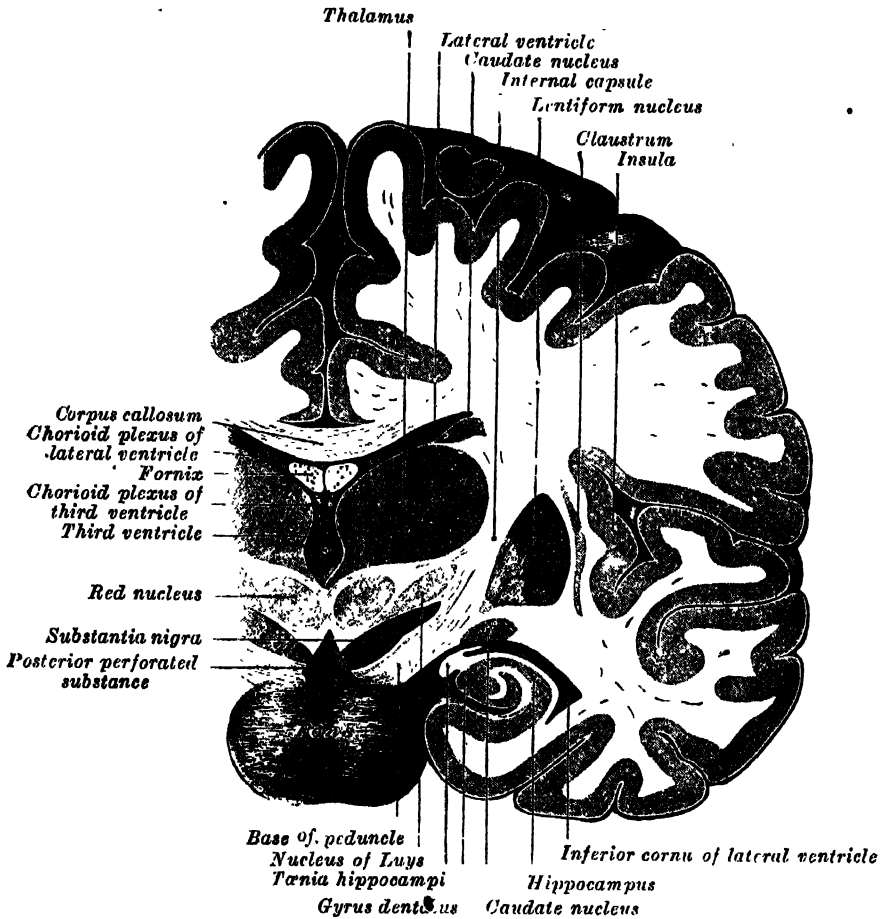
The *inferior surface* rests upon and is continuous with the upward prolongation of the tegmentum (*subthalamie tegmental region*), in front of which it is related to the *substantia innominata* of Meynert (p. 822).

The *medial surface* constitutes the upper part of the lateral wall of the third ventricle, and is connected to the corresponding surface of the opposite thalamus by a flattened grey band, the *massa intermedia* (middle or grey

commissure). This mass lies close behind the interventricular foramen, and averages about 1 cm. in its anteroposterior diameter: it sometimes consists of two parts, and occasionally is absent. It contains nerve-cells and nerve-fibres: a few of the latter may cross the middle line, but most of them pass towards the middle line and then curve lateralwards on the same side.

The *lateral surface* is in contact with a thick band of white substance which forms the occipital part of the internal capsule and separates the thalamus from the lentiform nucleus of the corpus striatum.

FIG. 761.—A coronal section of the brain immediately in front of the pons.

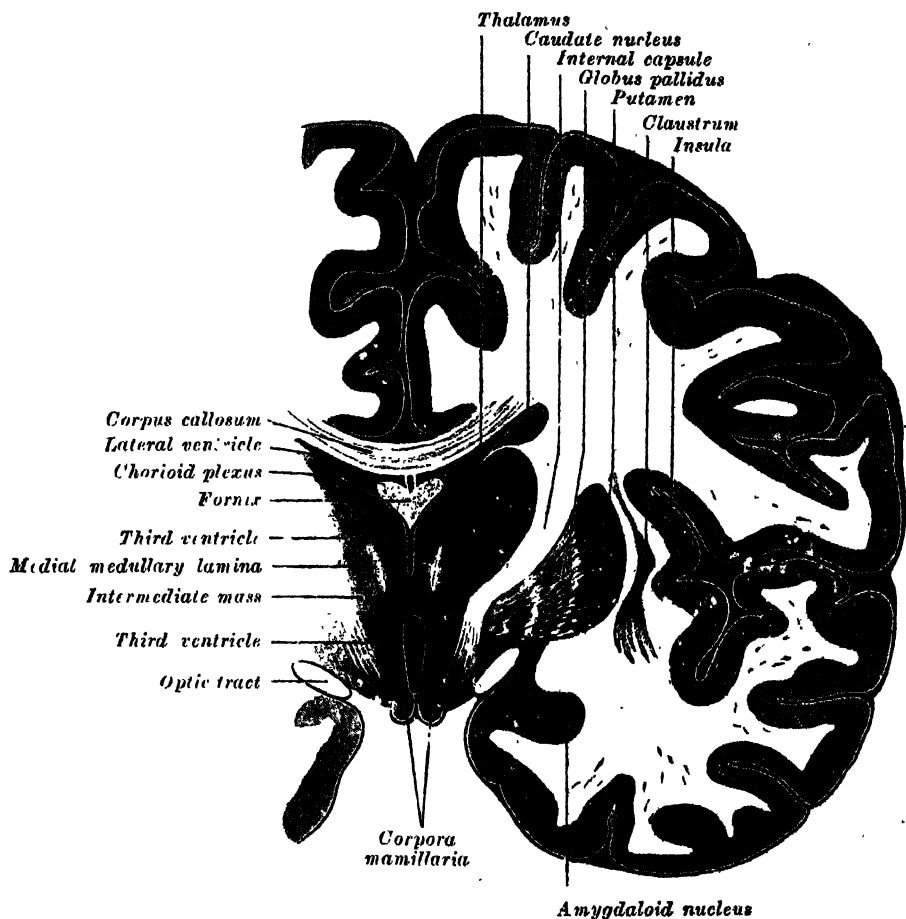


Structure.—The thalamus consists chiefly of grey substance, but its upper surface is covered by a layer of white substance, named the *stratum zonale*, and its lateral surface by a similar layer termed the *lateral medullary lamina*. Its grey substance is incompletely subdivided into three parts—*anterior*, *medial*, and *lateral*—by a white layer, the *medial medullary lamina*. The anterior part comprises the anterior tubercle, the medial part lies next the lateral wall of the third ventricle, while the lateral and largest part is interposed between the medullary laminae and includes the pulvinar. The lateral part is traversed by numerous fibres which radiate from the thalamus into the internal capsule, and pass through the latter to the cerebral cortex. These three parts are built up of numerous nuclei, the connexions of many of which are imperfectly known.

Connexions.—The thalamus may be regarded as a large ganglionic mass in which the ascending tracts of the tegmentum and a considerable proportion of the fibres of the optic tract end, and from the cells of which numerous fibres

(thalamocortical) take origin, and radiate to almost every part of the cerebral cortex. The lemniscus, together with the other longitudinal strands of the tegmentum, enters its ventral part: the thalamomammillary fasciculus (bundle of Vicq d'Azyr), from the corpus mamillare, enters its anterior tubercle, while many of the fibres of the optic tract terminate in its posterior end. The thalamus also receives numerous fibres (corticothalamic) from the cells of the cerebral cortex. The fibres that arise from the cells of the thalamus form four principal groups or stalks: (a) those of the *anterior stalk* pass through

FIG. 762.—A coronal section of the brain through the intermediate mass of the third ventricle.



the frontal part of the internal capsule to the frontal lobe; (b) the fibres of the *posterior stalk* (optic radiations) arise in the pulvinar and lateral geniculate body, and are conveyed through the occipital part of the internal capsule to the occipital lobe; (c) the fibres of the *inferior stalk* leave the under and medial surfaces of the thalamus, and pass beneath the lentiform nucleus to the temporal lobe and insula; (d) those of the *parietal stalk* pass from the lateral nucleus of the thalamus to the parietal lobe. Fibres also extend from the thalamus into the caudate and lentiform nuclei of the corpus striatum—those destined for the caudate nucleus leave the lateral surface, and those for the lentiform nucleus the inferior surface, of the thalamus.

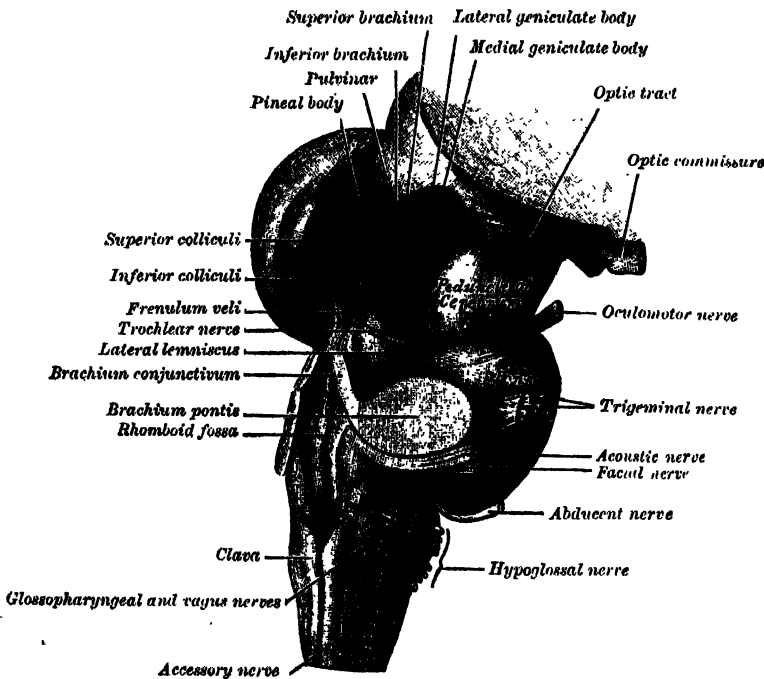
The *metathalamus* (fig. 763) comprises the geniculate bodies, which are two in number—a medial and a lateral—on either side.

The *medial geniculate body* lies under cover of the pulvinar of the thalamus and on the lateral aspect of the corpora quadrigemina. Oval in shape, with

its long axis directed forwards and lateralwards, it is lighter in colour and smaller in size than the lateral geniculate body. The inferior brachium from the inferior colliculus disappears under cover of it, while from its lateral extremity a strand of fibres passes to join the optic tract. Entering it are many acoustic fibres from the lateral lemniscus. The medial geniculate bodies are connected with one another by the commissure of Gudden, the fibres of which pass through the posterior part of the optic chiasma and form the medial parts of the optic tracts.

The *lateral geniculate body* is an oval elevation on the lateral part of the posterior end of the thalamus, and is connected with the superior colliculus by the superior brachium. It is of a dark colour, and presents a laminated arrangement consisting of alternate layers of grey and white substance. It

FIG. 768.—The hind- and mid-brains; posterolateral view.



receives numerous fibres from the optic tract, while other fibres of this tract pass over or through it into the pulvinar. Its cells are large and pigmented; their axons pass to the visual area in the occipital part of the cerebral cortex.

The superior colliculus, the pulvinar, and the lateral geniculate body receive many fibres from the optic tracts, and are termed the *lower visual centres*. Extirpation of the eyes in newly born animals entails an arrest of the development of these centres, but has no effect on the medial geniculate bodies or on the inferior colliculi. Moreover, the latter are well developed in the mole, an animal in which the superior colliculi are rudimentary.

The *epithalamus* comprises the trigonum habenulae, the pineal body, and the posterior commissure.

The *trigonum habenulae* is a small depressed triangular area situated in front of the superior colliculus and on the lateral aspect of the posterior part of the tectum thalami. It contains a group of nerve-cells termed the *ganglion habenulae*. Fibres enter it from the stalk of the pineal body, while others, forming what is termed the *habenular commissure*, pass across the middle line to the corresponding ganglion of the opposite side. Most of its fibres are, however, directed downwards and form a bundle, the *fasciculus retroflexus* of

Meynert, which passes medially to the red nucleus, and, after decussating with the corresponding fasciculus of the opposite side, ends in the interpeduncular ganglion.

The *pineal body* (fig. 760) is a small, conical, reddish-grey body which lies in the depression between the superior colliculi. It is placed beneath the splenium of the corpus callosum, but is separated from this by the tela chorioidea of the third ventricle, the lower layer of which envelops it. It measures about 8 mm. in length, and its base, directed forwards, is attached by a stalk or peduncle of white substance. The stalk divides anteriorly into two laminae, a dorsal and a ventral, which are separated from one another by the pineal recess of the third ventricle. The ventral lamina is continuous with the posterior commissure; the dorsal lamina is continuous with the habenular commissure and divides into two strands, termed the medullary striæ, which run forwards, one on either side, along the junction of the medial and upper surfaces of the thalamus to blend in front with the columns of the fornix.

Structure.—According to the careful investigations of Krabbe,* the pineal parenchyma consists of cells of three main varieties, namely (1) pineal cells, (2) glia-cells, and (3) nerve-cells. The pineal cells form the bulk of the parenchyma, and are of rounded shape with irregular nuclei poor in chromatin; at birth they exactly resemble the neuroblasts of the fetal brain. The glia-cells are relatively few in number, and give rise to a network of glia-fibres. The nerve-cells have scanty protoplasm and angular nuclei rich in chromatin; from the first year of life onward, they develop increasing numbers of out-running nerve-fibres with knobbed endings, and appear to have no connexion with the sympathetic fibres that accompany the blood-vessels. Connective tissue cells and fibrils appear in the pineal body during the first year of life, and habitually increase in quantity year by year, converting it into a pseudo-alveolar organ by the age of six or eight; the rate at which this fibrosis takes place is very variable. There is a connective tissue capsule, which is apparently free from unstriated muscle fibres in man. Calcareous concretions may be found in the pineal body at any age, and are constant after the seventeenth year, occurring mainly in the parenchyma and representing debris of the pineal cells. Spaces or cysts also occur normally in the pineal body, and may be either included portions of the embryonic pineal recess of the third ventricle and lined with ependyma, or due to degeneration of parts of the pineal parenchyma. Krabbe's researches lead him to conclude that the pineal body is neither a rudimentary nor a functionless organ, but that its various histological elements show signs of an unbalanced activity possibly due to variations in the pressure of the cerebrospinal fluid.

The human pineal body is phylogenetically homologous with the parietal eye of cyclostome fishes. Creutzfeldt has pointed out that it is best developed in ruminants and horses, but absent in elephants, seals, dasyurus, the mole, and many other animals, and he connects its presence with the possession of a relatively thin skin.

Applied Anatomy.—The function of the pineal body in the human body is very uncertain. Probably it has an internal secretion, though this is not proved. Possibly its function is to regulate the pressure of the cerebrospinal fluid. The growth of a tumour in the pineal body, itself of rare occurrence, has led in a few instances to sexual precocity or to obesity. The operative removal of the pineal body from puppies produces no abnormality in their subsequent development.

The *posterior commissure* is a rounded band of fibres crossing the middle line on the dorsal aspect of the upper end of the cerebral aqueduct. Its fibres acquire their medullary sheaths early, but their connexions have not been definitely determined. Most of them have their origin in a nucleus, the *nucleus of the posterior commissure*, which lies in the central grey substance of the upper end of the cerebral aqueduct, in front of the nucleus of the oculomotor nerve: some are probably derived from the posterior part of the thalamus and from the superior colliculus; others are believed to be continued downwards into the medial longitudinal fasciculus.

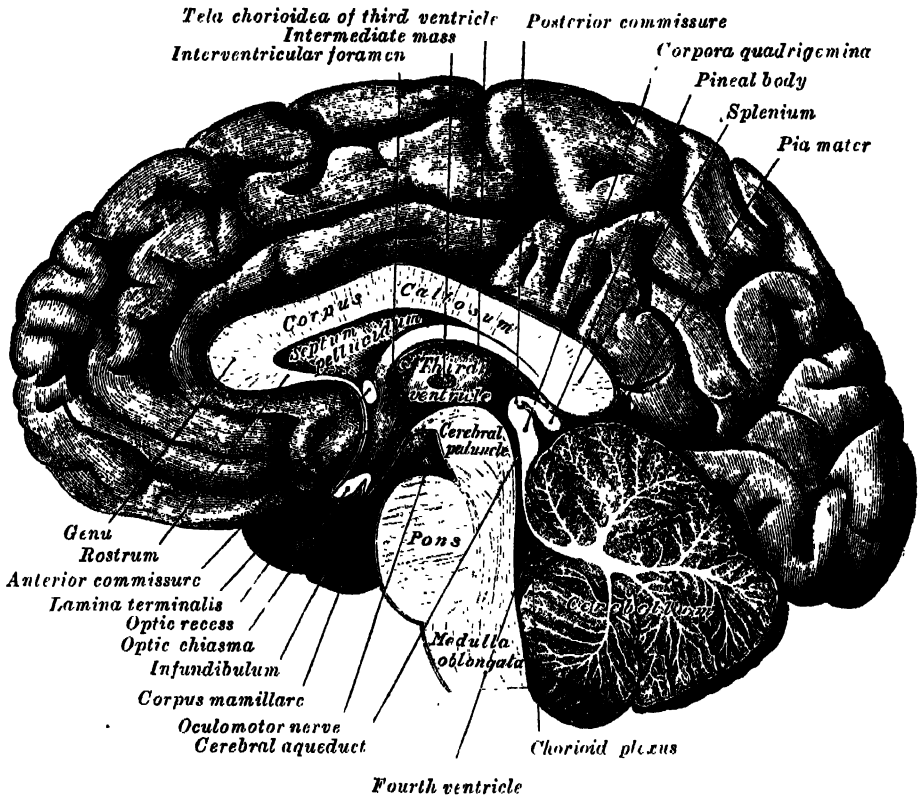
The *hypothalamus* (fig. 764) includes the subthalamie tegmental region and the structures forming the greater part of the floor of the third ventricle, viz. the corpora mamillaria, tuber cinereum, infundibulum, hypophysis, and optic chiasma.

The *subthalamie tegmental region* consists of the upward continuation of the tegmentum; it lies on the ventrolateral aspect of the thalamus and separates it from the fibres of the internal capsule. The red nucleus and the

* K. H. Krabbe, Abstract in *Review of Neurol. and Psychiatry*, Edinburgh, 1915, xiii, 300.

substantia nigra are prolonged into its lower part; in front it is continuous with the substantia innominata of Meynert, medially with the grey substance of the floor of the third ventricle. It consists from above downwards of three strata: (1) *stratum dorsale*, directly applied to the under surface of the thalamus and consisting of fine longitudinal fibres; (2) *zona incerta*, a continuation forwards of the formatio reticularis of the tegmentum; and (3) the *corpus subthalamicum* or *nucleus of Luys*, a brownish mass presenting a lenticular shape on transverse section, and situated on the dorsal aspect of the fibres of the base of the cerebral peduncle; it is encapsuled by a

FIG. 764.—A median sagittal section of the brain. The relations of the pia mater are indicated by the red colour.



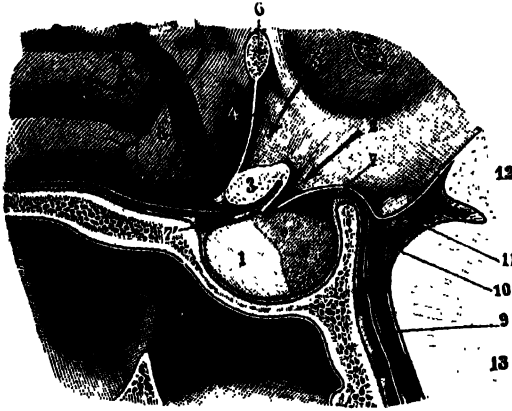
lamina of nerve-fibres and contains numerous medium-sized nerve-cells the connexions of which are as yet not fully determined.

The *corpora mamillaria* are two round white masses, each about the size of a small pea, placed side by side below the grey substance of the floor of the third ventricle in front of the posterior perforated substance. They consist of white substance externally and of grey substance internally, the cells of the latter forming two nuclei, a *medial* of smaller and a *lateral* of larger cells. The white substance is mainly formed by the fibres of the columns of the fornix, which descend to the base of the brain and end partly in the corpora mamillaria. From the cells of the grey substance of each mamillary body two fasciculi arise; one, the thalamomamillary fasciculus (bundle of Vicq d'Azyr), passes upwards into the anterior nucleus of the thalamus; the other is directed downwards into the tegmentum. Afferent fibres are believed to reach the corpus mamillare from the medial lemniscus and from the tegmentum.

The *tuber cinereum* is a hollow eminence of grey substance situated between the corpora mamillaria behind, and the optic chiasma in front. Laterally it is

continuous on either side with the anterior perforated substance, and anteriorly with a thin lamina, the *lamina terminalis*. From the under surface of the tuber cinereum a hollow conical process, the *infundibulum*, projects downwards and forwards and is attached to the posterior lobe of the hypophysis.

FIG. 765.—A sagittal section of the hypophysis cerebri, in situ. (Testut.)



- 1, 1'. Anterior and posterior lobes of hypophysis. 2. Infundibulum. 3. Optic chiasma. 4. Lamina terminalis. 5. Optic recess. 6. Anterior commissure. 7, 7'. Circular sinus. 8. Anterior cerebral artery. 9. Basilar artery. 10. Posterior cerebral artery. 11. Corpus mamillare. 12. Cerebral peduncle. 13. Pons.

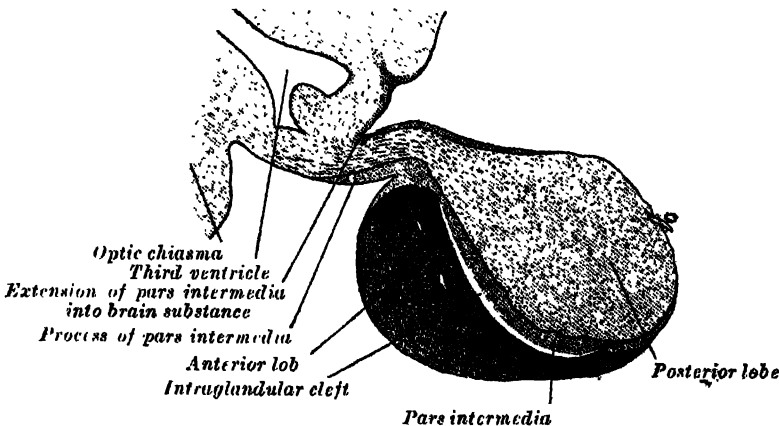
It is attached to the end of the infundibulum, and is situated in the fossa hypophyseos of the sphenoidal bone, where it is retained by a circular fold of dura mater, the *diaphragma sellæ*; this fold almost completely roofs in the fossa, leaving only a small central aperture through which the infundibulum passes.

In the lateral part of the tuber cinereum is a nucleus of nerve-cells, the *basal optic nucleus of Meynert*, while close to the cavity of the third ventricle are three additional nuclei.

Between the tuber cinereum and the corpora mamillaria a small elevation, with a corresponding depression in the third ventricle, is sometimes seen. Retzius has named it the *eminencia saccularis*, and regards it as a representative of the *saccus vasculosus* found in this situation in some of the lower vertebrates.

The *hypophysis* (pituitary body) (fig. 765) is a reddish-grey, somewhat oval mass, measuring about 12 mm. in its transverse, and 8 mm. in its anteroposterior diameter.

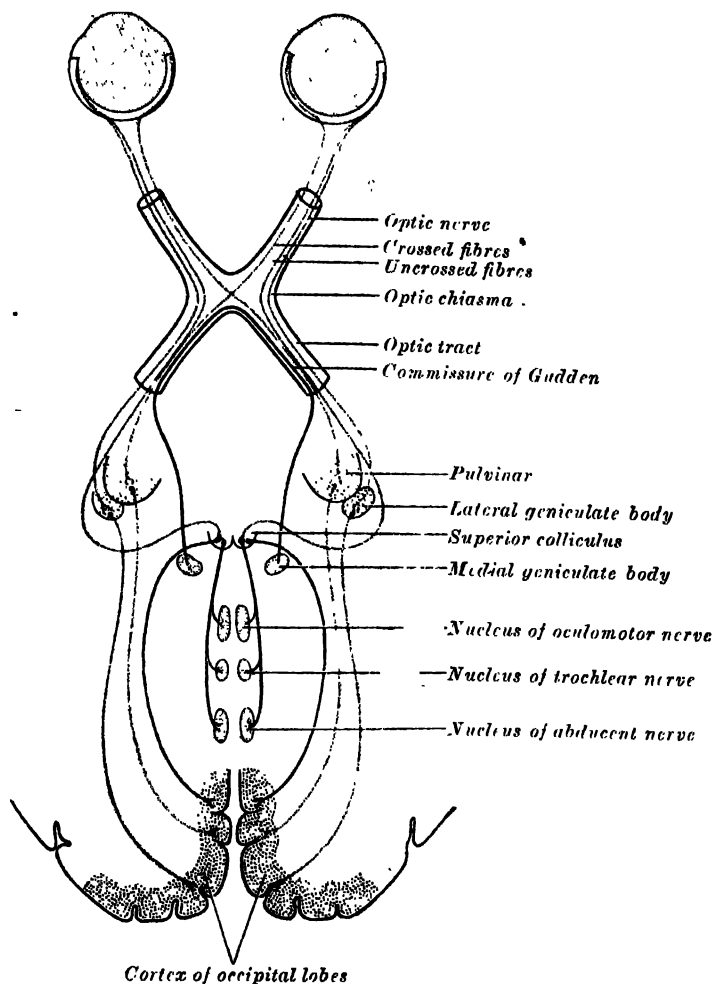
FIG. 766.—Median sagittal section through the hypophysis of an adult monkey. Semidiagrammatic. (Herring.)



The hypophysis consists of an anterior and a posterior lobe, which differ from one another in their mode of development and in their structure (fig. 766). The *anterior lobe* is the larger, and is somewhat kidney-shaped, the concavity being directed backwards and embracing the posterior lobe. It is developed from a diverticulum of the ectoderm of the primitive buccal cavity or stomodæum (p. 132), and consists of a *pars anterior* and a *pars intermedia*, separated from each other by a narrow cleft, the remnant of the pouch or diverticulum. The *pars anterior* is extremely vascular and consists of granular epithelial

Is of varying size and shape, arranged in cord-like trabeculae or alveoli and separated by large, thin-walled blood-vessels. The *pars intermedia* is a thin lamina closely applied to the body and neck of the posterior lobe; it contains few blood-vessels and consists of finely granular cells between which are small masses of colloid material. The *posterior lobe* is developed as a down-growth from the floor of the embryonic brain, and during early foetal life contains a cavity continuous with that of the third ventricle. In some animals

FIG. 767.—A scheme showing the central connexions of the optic nerves and optic tracts.



(e.g. cat) this cavity persists throughout life. Although of nervous origin the posterior lobe contains no nerve-cells or fibres. It consists of neuroglia-cells and fibres and is invaded by columns which grow into it from the *pars intermedia*; imbedded in it are scattered masses of a colloid substance histologically similar to that found in the thyroid gland. In certain of the lower vertebrates (e.g. fishes) nervous structures are present, and the lobe is of large size.

Applied Anatomy.—Prof. Schäfer has isolated from the *pars intermedia* a substance, no doubt an internal secretion, that causes constriction of the blood-vessels, rise of arterial blood-pressure, and increased secretion of urine, when injected subcutaneously. Enlargement of the hypophysis and of the cavity of the sella turcica are found in the rare disease *acromegaly*, which is characterised by gradual enlargement of the face, hands, and feet, with headache and often a peculiar type of blindness. This blindness is due to

the pressure of the enlarging hypophysis on the optic chiasma (fig. 765). The pressure causes atrophy, for the most part of the nerve-fibres coming from the nasal sides of the retina; with the result that the patient loses his two temporal fields of vision while retaining his nasal fields (bitemporal hemianopsy).

Optic chiasma.—The optic chiasma is a flattened, somewhat quadrilateral band of fibres, situated at the junction of the floor and anterior wall of the third ventricle. Most of its fibres have their origins in the retina, and reach the chiasma through the optic nerves, which are continuous with its antero-lateral angles. In the chiasma, they undergo a partial decussation (fig. 767); the fibres from the nasal half of the retina decussate and enter the optic tract of the opposite side, while the fibres from the temporal half of the retina do not undergo decussation, but pass back into the optic tract of the same side. In the posterior part of the commissure, however, is a strand of fibres, the *commissure of Gudden*, which is not derived from the optic nerves; it forms a connecting link between the medial geniculate bodies.

Optic tracts.—The optic tracts are continued backwards and lateralwards from the posterolateral angles of the optic chiasma. Each passes between the anterior perforated substance and the tuber cinereum, and, winding round the ventrolateral aspect of the cerebral peduncle, divides into a medial and a lateral root. The former comprises the fibres of Gudden's commissure and passes to the medial geniculate body. The lateral root consists mainly of afferent fibres which arise in the retina and undergo partial decussation in the optic chiasma, as described; but it also contains a few fine efferent fibres which have their origins in the brain and their terminations in the retina. When traced backwards, the afferent fibres of the lateral root are found to end in the lateral geniculate body and pulvinar of the thalamus, and in the superior colliculus; and these three structures constitute the *lower visual centres*. Fibres arise from the nerve-cells in these centres, and pass through the occipital part of the internal capsule, under the name of the *optic radiations*, to the cortex of the occipital lobe of the cerebrum, where the *higher or cortical visual centre* is situated. Some of the fibres of the optic radiations take an opposite course, arising from the cells of the occipital cortex and passing to the lower visual centres. Some fibres are detached from the optic tract, and pass through the cerebral peduncle to the nucleus of the oculomotor nerve. These may be regarded as the afferent branches for the Sphincter pupillæ and Ciliaris muscles. Other fibres have been described as reaching the cerebellum through the brachia conjunctiva; while others, again, are lost in the pons.

THE THIRD VENTRICLE

The **third ventricle** (figs. 760, 764, 768) is a median cleft between the two thalami. Behind, it communicates with the fourth ventricle through the cerebral aqueduct, and in front with the lateral ventricles through the inter-ventricular foramen. Somewhat triangular in shape with the apex directed backwards, it has a roof, a floor, an anterior and a posterior boundary, and a pair of lateral walls.

The **roof** (fig. 768) is formed by a layer of epithelium, which stretches between the upper edges of the lateral walls of the cavity and is continuous with the epithelial lining of the ventricle. It is covered by and adherent to a fold of pia mater, named the tela chorioidea of the third ventricle, from the under surface of which a pair of vascular fringed processes, the *chorioid plexuses of the third ventricle*, project downwards, one on either side of the middle line, and invaginate the epithelial roof into the ventricular cavity.

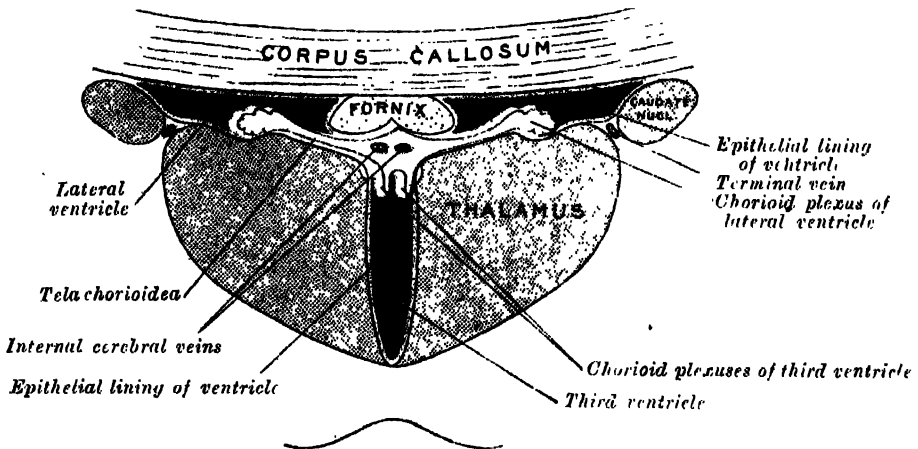
The **floor** slopes downwards and forwards and is formed mainly by the structures which constitute the hypothalamus: from before backwards these are: the optic chiasma, the infundibulum and tuber cinereum, and the corpora mammillaria. Behind the last, the floor is formed by the interpeduncular fossa and the tegmenta of the cerebral peduncles. The ventricle is prolonged downwards as a funnel-shaped recess, the *recessus infundibuli*, into the infundibulum, and to the apex of the latter the hypophysis is attached.

The **anterior boundary** is constituted below by the *lamina terminalis*, a thin layer of grey substance stretching from the upper surface of the optic chiasma

to the rostrum of the corpus callosum; above by the columns of the fornix and the anterior commissure. At the junction of the floor and anterior wall, immediately above the optic chiasma, the ventricle presents a small angular recess or diverticulum, the *optic recess*. Between the columns of the fornix, and above the anterior commissure, is a second recess termed the *vulva*. At the junction of the roof with the anterior and lateral walls of the ventricle, and situated between the thalami behind and the columns of the fornix in front, is the *interventricular foramen* (foramen of Monro) through which the third communicates with the lateral ventricles.

The *posterior boundary* is constituted by the pineal body, the posterior commissure and the cerebral aqueduct. A small recess, the *recessus pinealis*, projects into the stalk of the pineal body, whilst in front of and above the pineal body is a second recess, the *recessus suprapinealis*, consisting of a diverticulum of the epithelium which forms the ventricular roof.

FIG. 768.—A coronal section of the lateral and third ventricles. (Diagrammatic.)



Each *lateral wall* consists of an upper portion formed by the medial surface of the anterior two-thirds of the thalamus, and a lower consisting of an upward continuation of the grey substance of the ventricular floor. These two parts correspond to the alar and basal laminae respectively of the lateral wall of the fore-brain vesicle and are separated from each other by a furrow, the *sulcus of Monro*, which extends from the interventricular foramen to the cerebral aqueduct (p. 94). The lateral wall is limited above by the tænia thalami. The columns of the fornix curve downwards in front of the interventricular foramen, and then run in the lateral walls of the ventricle, where, at first, they form distinct prominences, but subsequently are lost to sight. The lateral walls are joined to each other across the cavity of the ventricle by a band of grey matter, the *massa intermedia* (p. 794).

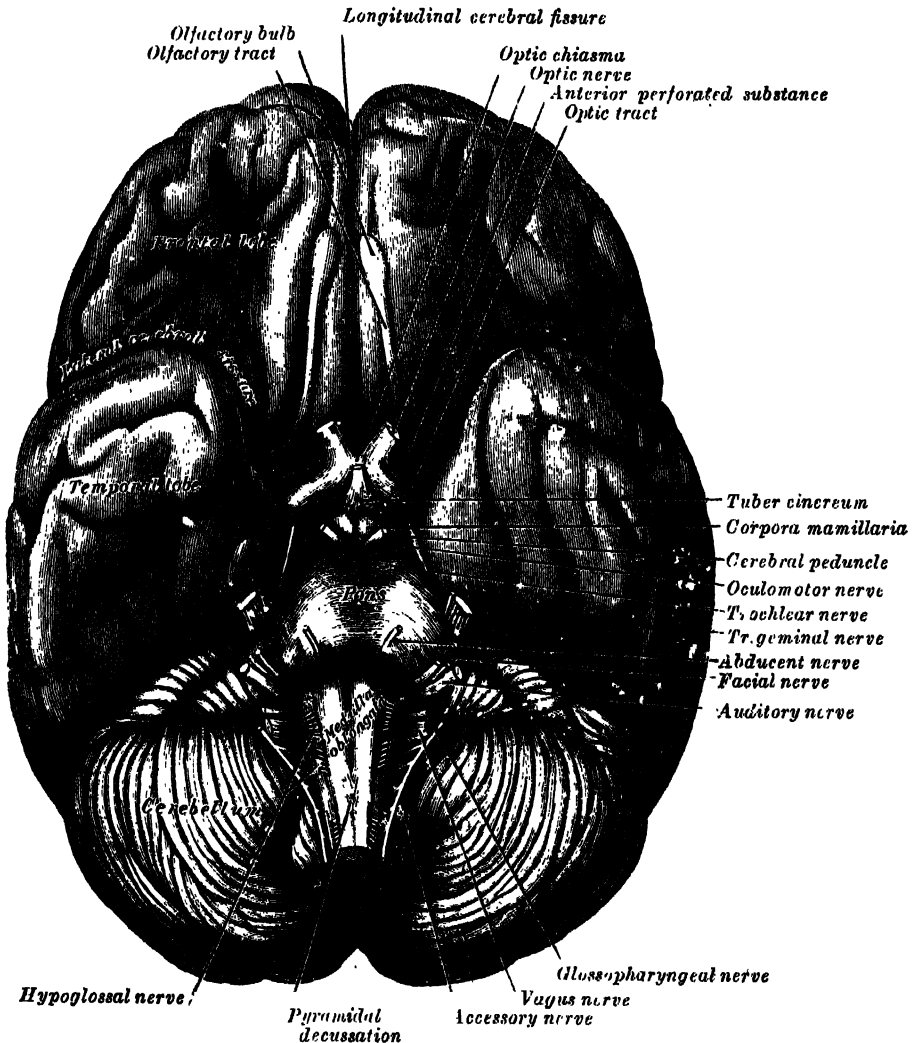
Interpeduncular fossa (fig. 769).—This is a somewhat lozenge-shaped area of the base of the brain, limited in front by the optic chiasma, behind by the anterosuperior surface of the pons, anterolaterally by the converging optic tracts and posterolaterally by the diverging cerebral peduncles. The structures contained in it have already been described; from behind forwards they are the posterior perforated substance, corpora mamillaria, tuber cinereum, infundibulum, and hypophysis.

THE TELENCEPHALON

The **telencephalon** includes: (1) the cerebral hemispheres with their cavities, the lateral ventricles; and (2) the pars optica hypothalami and

the anterior portion of the third ventricle (already described under the dien-cephalon). As intimated in the chapter on Embryology (p. 96), each cerebral hemisphere may be divided into three fundamental parts, viz. the rhinencephalon, the corpus striatum, and the neopallium. The rhinencephalon, associated with the sense of smell, is the oldest part of the telencephalon, and

FIG. 769.—The base of the brain.



forms almost the whole of the hemisphere in some of the lower animals (e.g. fishes, amphibians, and reptiles). In man it is rudimentary, whereas the neopallium undergoes great development and forms the chief part of the hemisphere.

THE CEREBRAL HEMISPHERES

The cerebral hemispheres constitute the largest part of the brain, and, when viewed together from above, assume the form of an ovoid mass broader behind than in front, the greatest transverse diameter corresponding with a line connecting the two parietal tuberosities. The hemispheres are separated by a deep median cleft, named the *longitudinal cerebral fissure*, and each possesses a central cavity, the lateral ventricle.

The longitudinal cerebral fissure contains a sickle-shaped process of dura mater, the *falx cerebri*. In front and behind, the fissure extends from the upper to the under surfaces of the hemispheres and completely separates them, but its middle portion only separates them for about one-half of their vertical extent; for at this part they are connected across the middle line by a great central white commissure, the *corpus callosum*.

In a median sagittal section (fig. 764) the cut corpus callosum presents the appearance of a broad, arched band. Its thick posterior end, termed the *splenium*, overlaps the mid-brain, but is separated from it by the tela chorioidea of the third ventricle and the pineal body. Its anterior curved end, termed the *genu*, gradually tapers into a thinner portion, the *rostrum*, which is continued downwards and backwards in front of the anterior commissure to join the lamina terminalis. Arching backwards from immediately behind the anterior commissure to the under surface of the splenium is a second white band named the *fornix*; between this and the corpus callosum are the laminae and cavity of the septum pellucidum.

SURFACES OF THE CEREBRAL HEMISPHERES

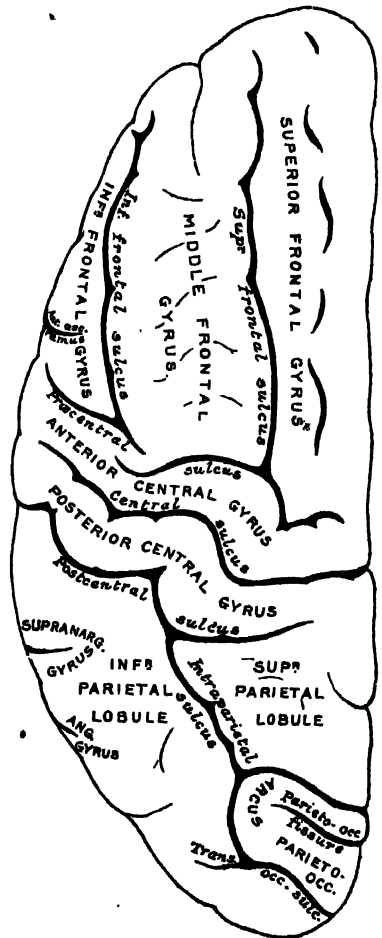
Each hemisphere presents three surfaces: lateral, medial, and inferior.

The *lateral surface* is convex in adaptation to the concavity of the corresponding half of the vault of the cranium. The *medial surface* is flat and vertical and is separated from that of the opposite hemisphere by the longitudinal fissure and the falx cerebri. The *inferior surface* is of an irregular form, and may be divided into three areas: anterior, middle, and posterior. The anterior area, formed by the orbital surface of the frontal lobe, is concave, and rests on the roof of the orbit and nose; the middle area is convex, and consists of the under surface of the temporal lobe: it is adapted to the corresponding half of the middle cranial fossa. The posterior area is concave, directed medialwards as well as downwards, and is named the *tentorial surface*, since it rests upon the tentorium cerebelli, which intervenes between it and the upper surface of the cerebellum.

These three surfaces are separated from each other by the following borders: (a) *superomedial*, between the lateral and medial surfaces; (b) *inferolateral*, between the lateral and inferior surfaces; the anterior part of this border separates the lateral from the orbital surface, and is known as the *superciliary* border; (c) *medial occipital*, between the tentorial and medial surfaces; and (d) *medial orbital*, separating the orbital from the medial surface. The anterior end of the hemisphere is named the *frontal pole*; the posterior, the *occipital pole*; and the anterior end of the temporal lobe, the *temporal pole*. About 5 cm. in front of the occipital pole on the inferolateral border is an indentation or notch, named the *pre-occipital notch*.

The surfaces of the hemispheres are moulded into a number of irregular eminences, named *gyri* or *convolutions*, and separated by furrows termed *fissures* and *sulci*. The furrows are of two kinds, *complete* and *incomplete*. The former

FIG. 770.—The lateral surface of the left cerebral hemisphere, viewed from above.

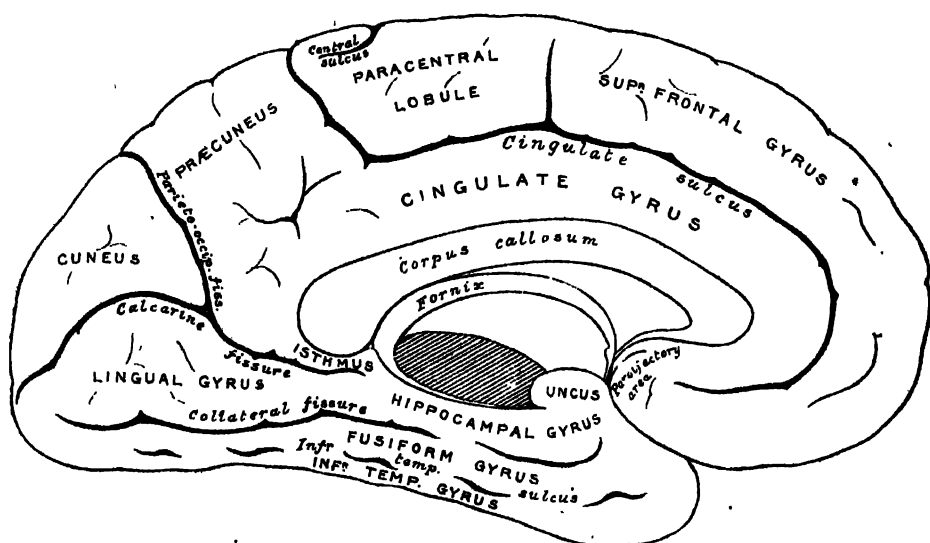


concavity directed forwards, and an *inferior genu* with its concavity directed backwards. The central sulcus forms an angle, opening forwards, of about 70° with the median plane.

The parieto-occipital fissure.—Only a small part of this fissure is seen on the lateral surface of the hemisphere, its chief part being on the medial surface. The *lateral part* (fig. 771) is situated about 5 cm. in front of the occipital pole of the hemisphere, and measures about 1.25 cm. in length. The *medial part* (fig. 772) runs downwards and forwards as a deep cleft on the medial surface of the hemisphere, and joins the calcarine fissure below and behind the posterior end of the corpus callosum. In most cases it contains a submerged gyrus.

The calcarine fissure (fig. 772) is on the medial surface of the hemisphere. It begins near the occipital pole in two converging rami, and runs forward, at first with an upward, and then with a downward, curve; it ends in the posterior part of the gyrus hippocampi, just below the splenium of the corpus

FIG. 772.—The medial surface of the left cerebral hemisphere.



callosum; a little behind the splenium it is joined at an acute angle by the medial part of the parieto-occipital fissure. The anterior part of this fissure gives rise to the prominence of the *calcar avis* in the posterior cornu of the lateral ventricle.

The cingulate sulcus (fig. 772) is on the medial surface of the hemisphere; it begins below the anterior end of the corpus callosum and runs upwards and forwards nearly parallel to the rostrum of this body; it curves in front of the genu, is continued backwards above the corpus callosum, and finally ascends to the superomedial border of the hemisphere a short distance behind the upper end of the central sulcus. It separates the superior frontal from the cingulate gyrus.

The collateral fissure (fig. 772) is on the tentorial surface of the hemisphere, and extends from near the occipital pole to within a short distance of the temporal pole. Behind, it lies below and lateral to the calcarine fissure, from which it is separated by the lingual gyrus; in front, it is situated between the hippocampal gyrus and the anterior part of the fusiform gyrus.

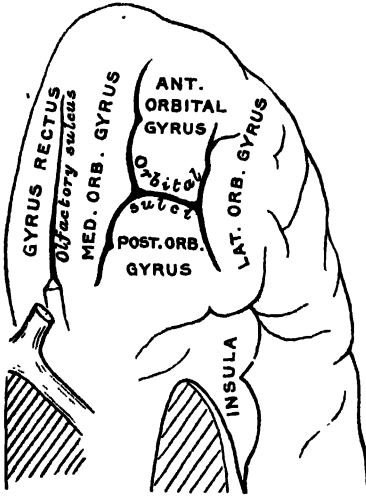
The circular sulcus (*sulcus limitans insulæ*) (fig. 775) is on the lower and lateral surfaces of the hemisphere: it surrounds the insula (p. 811) and separates it from the frontal, parietal, and temporal lobes.

Lobes of the hemispheres.—By means of these fissures and sulci, assisted by certain arbitrary lines, each hemisphere is divided into the following lobes; *frontal, parietal, temporal, occipital, limbic, and the insula.*

Frontal lobe.—On the lateral surface of the hemisphere this lobe extends from the frontal pole to the central sulcus, the latter separating it from the parietal lobe. Below, it is limited by the posterior ramus of the lateral fissure, which intervenes between it and the temporal lobe. On the medial surface, it is separated from the cingulate gyrus by the cingulate sulcus; and on the inferior surface, it is bounded behind by the stem of the lateral cerebral fissure.

The *lateral surface* of the frontal lobe (fig. 771) is traversed by three sulci which divide it into four gyri: the sulci are named the precentral, and the superior and inferior frontal; the gyri are the anterior central, and the superior, middle, and inferior frontal. The *precentral sulcus* runs parallel to the central sulcus, and is usually divided into an upper and a lower part; between it and the central sulcus is the anterior central gyrus. From the precentral sulcus, the *superior and inferior frontal sulci* run forwards and downwards, and divide the remainder of the lateral surface of the lobe into three parallel gyri, named, respectively, the superior, middle, and inferior frontal gyri.

FIG. 773.—The orbital surface of the left frontal lobe.



The *anterior central gyrus* is bounded in front by the precentral sulcus, behind by the central sulcus; it extends from the superomedial border of the hemisphere to the posterior ramus of the lateral cerebral fissure.

The *superior frontal gyrus* is situated above the superior frontal sulcus and is continued on to the medial surface of the hemisphere. The portion on the lateral surface of the hemisphere is more or less completely subdivided into an upper and a lower part by the *paramedial sulcus*, which, however, is frequently interrupted by bridging gyri.

The *middle frontal gyrus*, between the superior and inferior frontal sulci, is continuous with the anterior orbital gyrus on the inferior surface of the frontal lobe; it is

frequently subdivided into two by a horizontal sulcus, the *medial frontal sulcus* of Eberstaller, which ends anteriorly in a wide bifurcation.

The *inferior frontal gyrus* lies below the inferior frontal sulcus, and is continuous with the lateral and posterior orbital gyri on the inferior surface of the frontal lobe. The anterior horizontal and ascending rami of the lateral cerebral fissure subdivide it into three parts, viz.: (1) the *orbital part*, below the anterior horizontal ramus of the fissure; (2) the *triangular part* ('cap' of Broca), between the ascending and horizontal rami; and (3) the *basilar part*, behind the anterior ascending ramus. The left inferior frontal gyrus is, as a rule, more highly developed than the right, and is named the *gyrus of Broca*, from the fact that Broca described it as the centre for articulate speech.

The *inferior or orbital surface* of the frontal lobe (fig. 773) is concave, and rests on the orbital plate of the frontal bone. It is divided by an H-shaped *orbital sulcus* into four gyri. These are named, from their position, the *medial*, *anterior*, *lateral*, and *posterior orbital gyri*. The medial orbital gyrus presents a well-marked anteroposterior sulcus, the *olfactory sulcus*, for the olfactory tract; the portion medial to this is named the *gyrus rectus*, and is continuous with the superior frontal gyrus on the medial surface.

The *medial surface* of the frontal lobe is occupied by the medial part of the superior frontal gyrus (marginal gyrus) (fig. 772). It lies between the cingulate sulcus and the superomedial margin of the hemisphere. The posterior part of this gyrus is sometimes marked off by a vertical sulcus, and is named the *paracentral lobule*; it is continuous, over the superomedial border of the hemisphere, with the anterior and posterior central gyri.

Parietal lobe.—The parietal lobe is separated from the frontal lobe by the central sulcus, but its boundaries below and behind are not so definite.

Posteriorly, it is limited by the lateral part of the parieto-occipital fissure, and by a line carried across the hemisphere from the lateral end of this fissure to the pre-occipital notch. Below, it is separated from the temporal lobe by the posterior ramus of the lateral fissure, and by a line carried backwards from it to meet the line passing downwards to the pre-occipital notch.

The *lateral surface* of the parietal lobe (fig. 771) is cleft by a well-marked furrow, the *intraparietal sulcus* of Turner, which consists of an oblique and a horizontal portion. The oblique part is named the *postcentral sulcus*, and commences below, about midway between the lower end of the central sulcus and the upturned end of the lateral fissure. It runs upwards and backwards, parallel to the central sulcus, and is sometimes divided into an *upper* and a *lower* ramus. It forms the hinder limit of the posterior central gyrus.

From about the middle of the postcentral sulcus, or from the upper end of its inferior ramus, the *horizontal portion* of the intraparietal sulcus is carried backwards and slightly upwards on the parietal lobe, and is prolonged, under the name of the *occipital ramus*, into the occipital lobe, where it divides into two parts, which form nearly a right angle with the main stem and constitute the *transverse occipital sulcus*. The part of the parietal lobe above the horizontal portion of the intraparietal sulcus is named the superior parietal lobule; the part below, the inferior parietal lobule.

The *posterior central gyrus* extends from the longitudinal fissure above to the posterior ramus of the lateral fissure below. It lies parallel with the anterior central gyrus, and is connected with it below, and sometimes also above, the central sulcus.

The *superior parietal lobule* is bounded in front by the upper part of the postcentral sulcus, but is usually connected with the posterior central gyrus above the end of the sulcus; behind it, is the lateral part of the parieto-occipital fissure, round the end of which it is joined to the occipital lobe by a curved gyrus, the *arcus parietooccipitalis*; below, it is separated from the inferior parietal lobule by the horizontal portion of the intraparietal sulcus.

The *inferior parietal lobule* lies below the horizontal portion of the intraparietal sulcus, and behind the lower part of the postcentral sulcus. It is divided from before backwards into two gyri. One, the *supramarginal*, arches over the upturned end of the lateral fissure; it is continuous in front with the postcentral gyrus, and behind with the superior temporal gyrus. The second, the *angular*, arches over the posterior end of the superior temporal sulcus, behind which it is continuous with the middle temporal gyrus.

The *medial surface* of the parietal lobe (fig. 772) is bounded behind by the medial part of the parieto-occipital fissure; in front, by the posterior end of the cingulate sulcus; and below, it is separated from the cingulate gyrus by the *subparietal sulcus*. It consists of a square-shaped convolution, termed the *præcuneus* or *quadrate lobe*.

Occipital lobe.—The occipital lobe is small and pyramidal in shape; it presents three surfaces: lateral, medial, and tentorial.

The *lateral surface* is limited in front by the lateral part of the parieto-occipital fissure, and by a line carried from the end of this fissure to the pre-occipital notch; it is traversed by the transverse occipital and the lateral occipital sulci. The *transverse occipital sulcus* is continuous with the posterior end of the occipital ramus of the intraparietal sulcus, and runs across the upper part of the lobe, a short distance behind the parieto-occipital fissure. The *lateral occipital sulcus* extends from behind forwards, and divides the lateral surface of the occipital lobe into a *superior* and an *inferior gyrus*, which are continuous in front with the parietal and temporal lobes.*

The *medial surface* of the occipital lobe is bounded in front by the medial part of the parieto-occipital fissure, and is traversed by the calcarine fissure, which subdivides it into the cuneus and the lingual gyrus. The *cuneus* is a wedge-shaped area between the calcarine fissure and the medial part of the parieto-occipital fissure. The *lingual gyrus* lies between the calcarine fissure and the posterior part of the collateral fissure; behind, it reaches the occipital pole; in front, it joins the hippocampal gyrus.

* Elliot Smith has named the lateral occipital sulcus the *sulcus lunatus*, and regards it as the representative, in the human brain, of the 'Affenspalte' of the brain of the ape.

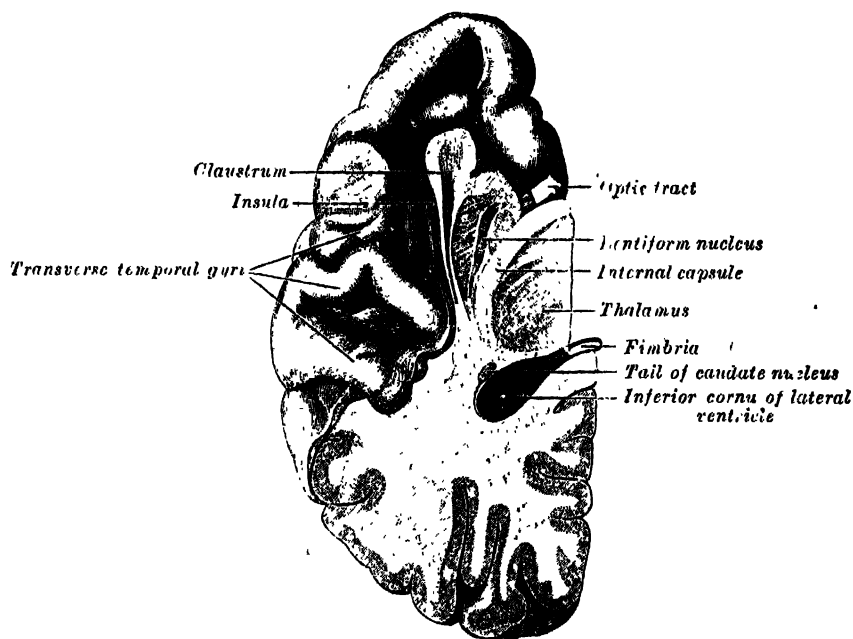
The *tentorial surface* of the occipital lobe is limited in front by an imaginary transverse line through the pre-occipital notch, and consists of the posterior part of the *fusiform gyrus* and the lower part of the lingual gyrus, which are separated from each other by the posterior segment of the collateral fissure.

Temporal lobe.—The temporal lobe presents superior, lateral, and inferior surfaces.

The *superior surface* forms the lower limit of the lateral cerebral fissure and overlaps the *insula*. On opening out the lateral fissure, three or four gyri will be seen springing from the depth of the hinder end of the fissure, and running obliquely forwards and outwards on the posterior part of the upper surface of the superior temporal gyrus; these are named the *transverse temporal gyri* (Heschl) (fig. 774).

The *lateral surface* (fig. 771) is bounded above by the posterior ramus of the lateral fissure, and by an imaginary line continued backwards from it; below,

Fig. 774.—A section showing the upper surface of the temporal lobe.



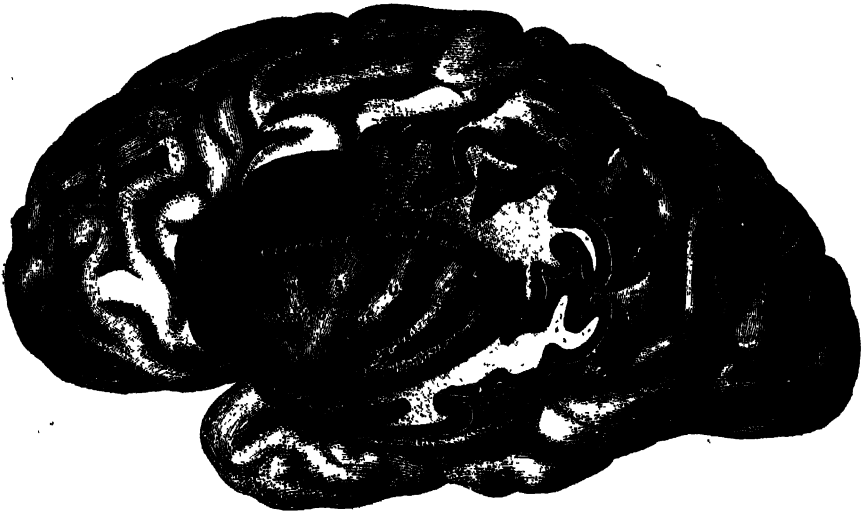
it is limited by the inferolateral border of the hemisphere. It is divided into superior, middle, and inferior gyri by the superior and middle temporal sulci. The *superior temporal sulcus* runs from before backwards across the temporal lobe, some little distance below, but parallel with, the posterior ramus of the lateral fissure; and hence it is often termed the *parallel sulcus*. The *middle temporal sulcus* takes the same direction as the superior, but is situated at a lower level, and is usually subdivided into two or more parts. The *superior temporal gyrus* lies between the posterior ramus of the lateral cerebral fissure and the superior temporal sulcus, and is continuous behind with the supra-marginal and angular gyri. The *middle temporal gyrus* is between the superior and middle temporal sulci, and is joined posteriorly with the angular gyrus. The *inferior temporal gyrus* is placed below the middle temporal sulcus, and is connected behind with the inferior occipital gyrus; it also extends round the inferolateral border on to the inferior surface of the temporal lobe, where it is limited by the inferior temporal sulcus.

The *inferior surface* is concave, and is continuous posteriorly with the tentorial surface of the occipital lobe. It is traversed by the *inferior temporal sulcus*, which extends from near the occipital pole behind, to within a short distance of the temporal pole in front, but is frequently subdivided by bridging

Lateral to this fissure is the narrow tentorial part of the inferior temporal gyrus, and medial to it the *fusiform gyrus*, which extends from the occipital to the temporal pole; this gyrus is limited medially by the collateral fissure, which separates it from the lingual gyrus behind and from the hippocampal gyrus in front.

The *insula* (island of Reil) (fig. 775) lies deeply in the lateral cerebral fissure, and is surrounded by the circular sulcus (p. 807); it can only be seen when the lips of the lateral cerebral fissure are widely separated, since it is overlapped and hidden by the gyri which bound the fissure. These gyri are termed the *opercula of the insula*, they are separated from each other by the three rami of the lateral fissure, and are named the orbital, frontal, frontoparietal, and temporal opercula. The *orbital operculum* lies below the anterior horizontal ramus of the fissure, the *frontal* between this and the anterior ascending ramus, the *frontoparietal* between the anterior ascending ramus and

FIG. 775.—The insula of the left side, exposed by removing the opercula.



the upturned end of the posterior ramus, and the *temporal* below the posterior ramus. The frontal operculum is of small size in those cases where the anterior horizontal and ascending rami of the lateral fissure arise from a common stem. When the opercula have been removed, the insula is seen as a triangular eminence, the apex of which is directed towards the anterior perforated substance. It is divided into a larger anterior and a smaller posterior part by a deep sulcus (*sulcus centralis insulae*) which runs backwards and upwards from the apex of the insula. The anterior part is subdivided by shallow sulci into three or four *short gyri*, while the posterior part is formed by one *long gyrus*, which is often divided at its upper end. The cortical grey substance of the insula is continuous with that of the different opercula, while its deep surface corresponds with the lentiform nucleus of the corpus striatum.

Limbic lobe (fig. 772).—The term limbic lobe was introduced by Broca, and under it he included the cingulate and hippocampal gyri, which together arch round the corpus callosum and the hippocampal fissure. These he separated on the morphological ground that they are well developed in animals possessing a keen sense of smell (osmatic animals), such as the dog and fox.

The *cingulate gyrus* is an arched-shaped convolution, lying in close relation to the superficial surface of the corpus callosum, from which it is separated by a slit-like fissure, the *callosal fissure*. It commences below the rostrum of the corpus callosum, curves round in front of the genu, extends along the upper surface of the body, and finally turns downwards behind the splenium, where it is connected by a narrow *isthmus* with the hippocampal gyrus. It is

separated from the medial part of the superior frontal gyrus by the cingulate sulcus, and from the præcuneus by the subparietal sulcus.

The *hippocampal gyrus* is bounded above by the hippocampal fissure, and below by the anterior part of the collateral fissure. Behind, it is continuous superiorly, through the isthmus, with the cingulate gyrus and inferiorly with the lingual gyrus. Running in the substance of the cingulate and hippocampal gyri, and connecting them together, is a tract of arched fibres, named the *cingulum* (p. 528). The anterior extremity of the hippocampal gyrus is recurved in the form of a hook (*uncus*), which is separated from the apex of the temporal lobe by a slight fissure, the *incisura temporalis*. Although superficially continuous with the hippocampal gyrus, the uncus forms morphologically a part of the rhinencephalon.

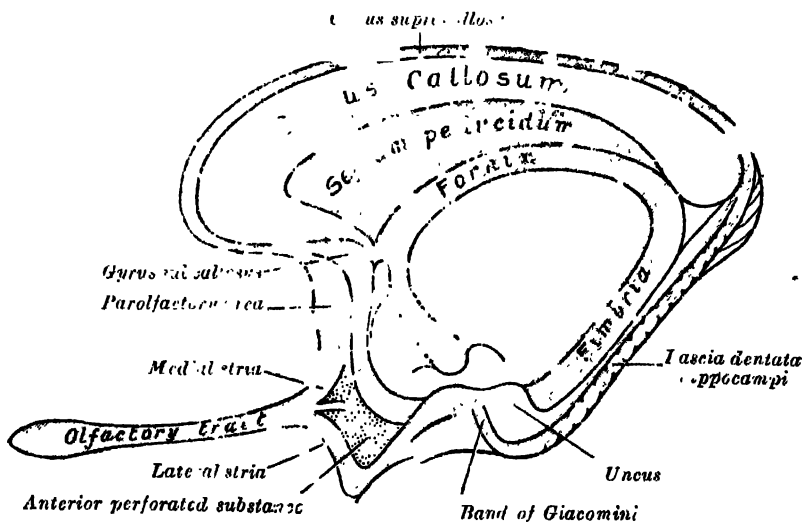
The hippocampal fissure begins immediately behind the splenium of the corpus callosum, and runs forwards between the hippocampal and dentate gyri to end in the uncus. It is a complete fissure (p. 806), and gives rise to the prominence of the hippocampus in the inferior cornu of the lateral ventricle.

RHINENCEPHALON

The *rhinencephalon* (Fig. 776) comprises the olfactory lobe, the uncus, the subcallosal and supracallosal gyri, the fascia dentata hippocampi, the septum pellucidum, the fornix and the hippocampus.

1. The *olfactory lobe* is situated under the inferior or orbital surface of the frontal lobe. It may be vibrates it as a well-marked portion

Fig. 776.—A scheme of the rhinencephalon.



of the hemisphere and contains an extension of the lateral ventricle; but in man and some other mammals it is rudimentary. It consists of the olfactory bulb and tract, the olfactory trigone, the parolfactory area of Broca, and the anterior perforated substance.

(a) The *olfactory bulb* is an oval, reddish-grey mass which lies above the lamina cribrosa of the ethmoidal bone, and forms the anterior expanded extremity of the olfactory tract. The olfactory nerves pass upwards through the lamina cribrosa from the olfactory region of the nasal cavity and enter the inferior surface of the olfactory bulb. Its minute structure is described on p. 833.

(b) The *olfactory tract* is a narrow white band, triangular on coronal section, the apex being directed upwards. It lies in the olfactory sulcus on the inferior

surface of the frontal lobe, and divides posteriorly into two striae, a medial and a lateral. The *lateral stria* is directed across the lateral part of the anterior perforated substance and then bends abruptly medialwards towards the uncus of the hippocampal gyrus. The *medial stria* turns medialwards behind the parolfactory area and ends in the subcallosal gyrus; in some cases a small *intermediate stria* is seen running backwards to the anterior perforated substance.

(c) The *olfactory trigone* is a small triangular area in front of the anterior perforated substance. Its apex, directed forwards, occupies the posterior part of the olfactory sulcus, and is brought into view by throwing back the olfactory tract.

(d) The *parolfactory area of Broca* is a small triangular field on the medial surface of the hemisphere in front of the subcallosal gyrus, from which it is separated by the posterior parolfactory sulcus; it is continuous below with the olfactory trigone, and above and in front with the cingulate gyrus; it is limited anteriorly by the *anterior parolfactory sulcus*.

(e) The *anterior perforated substance* is an irregularly quadrilateral area in front of the optic tract and behind the olfactory trigone, from which it is separated by the *fissura prima*; medially and in front it is continuous with the subcallosal gyrus; laterally it is bounded by the lateral stria of the olfactory tract and is continued into the uncus. Its grey substance is confluent above with that of the corpus striatum, and is perforated anteriorly by numerous small blood-vessels.

2. The uncus has already been described (p. 812) as the recurved, hook-like portion of the hippocampal gyrus.

3. The subcallosal, precallosal, and dentate gyri form a rudimentary arch shaped in part by grey substance extending over the corpus callosum and above the hippocampal gyrus to the anterior perforated substance to the uncus.

(a) The *subcallosal gyrus* (peduncle of the corpus callosum) is a narrow lamina on the medial surface of the hemisphere in front of the *arteria terminalis*, behind the parolfactory area, and below the posterior part of the corpus callosum. It is continuous around the genu of the corpus callosum with the supracallosal gyrus.

(b) The *supracallosal gyrus* or *callosum gyrus* consists of a thin layer of grey substance in contact with the upper surface of the corpus callosum and continuous laterally with the grey substance of the cingulate gyrus. It contains two longitudinally directed strands of white substance, the *medial* and *lateral longitudinal striae*. The supracallosal gyrus is prolonged round the splenium of the corpus callosum as a delicate band, the *fascia cuneata*, which is continuous below with the fascia dentata of the hippocampus.

(c) The *fascia dentata hippocampi* (dentate gyrus) is a narrow band extending downwards and forwards above the hippocampal gyrus but separated from it by the hippocampal fissure, its free margin is notched, and is overlapped by the fimbria—the *fimbriodentate fissure* intervening. Anteriorly it is continued into the notch of the uncus, where it bends sharply and is then prolonged as a delicate band, the *band of Giacomini*, over the uncus, on the lateral surface of which it is lost.

The remaining parts of the rhinencephalon, viz. the septum pellucidum, the fornix, and the hippocampus, will be described in connexion with the lateral ventricle.

INTERIOR OF THE CEREBRAL HEMISPHERES

If the upper part of either hemisphere be removed, at a level about 1.25 cm. above the corpus callosum, the central white substance will be exposed as an oval-shaped area, the *centrum ovale minus*, surrounded by a narrow convoluted margin of grey substance, and studded with numerous minute red dots (*puncta vasculosa*), produced by the escape of blood from divided blood-vessels. If the remaining portions of the hemispheres be drawn slightly apart a broad band of white substance, the *corpus callosum*, will be observed, connecting them at the bottom of the longitudinal fissure; the margins of the hemispheres

which overlap the corpus callosum are called the *labia cerebri*. Each labium is part of the cingulate gyrus already described; and the slit-like interval between it and the upper surface of the corpus callosum is termed the *callosal fissure* (fig. 772). If the hemisphere be sliced off until level with the upper surface of the corpus callosum, the white substance of that structure will be seen connecting the two hemispheres.* The large expanse of medullary matter now exposed, surrounded by the convoluted margin of grey substance, is called the *centrum ovale majus*.

The corpus callosum (fig. 777) is the great transverse commissure which unites the cerebral hemispheres and roofs in the lateral ventricles. A good

FIG. 777.—The corpus callosum, from above.



conception of its position and size is obtained by examining a median sagittal section of the brain (fig. 764), when it is seen to form an arched structure about 10 cm. long. Its anterior end is about 4 cm. from the frontal pole, and its posterior end about 6 cm. from the occipital pole, of the hemisphere.

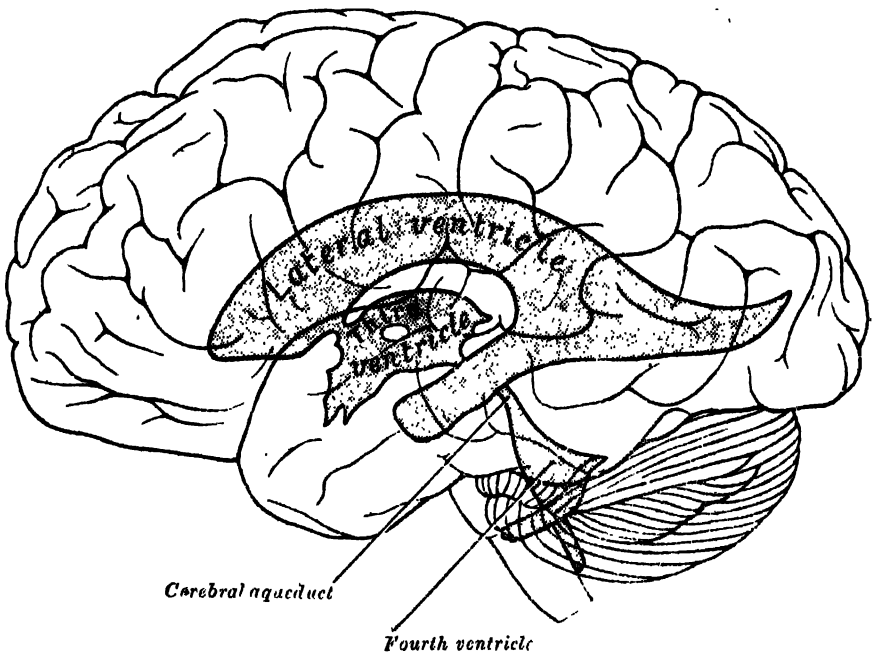
The *anterior end* is named the *genu*, and is bent downwards and backwards in front of the septum pellucidum; diminishing rapidly in thickness, it is prolonged backwards, under the name of the *rostrum*, which is connected below with the lamina terminalis. The anterior cerebral arteries are in contact with the under surface of the rostrum; they then arch over the front of the genu, and are carried backwards above the body of the corpus callosum.

* A better view of the corpus callosum, and of the way in which its fibres pass into the hemisphere, is obtained by inserting the fingers into the callosal fissure and tearing off the cingulate gyrus in a lateral direction.

The *posterior end* is termed the *splenium*, and constitutes the thickest part of the corpus callosum. It overlaps the *tela chorioidea* of the third ventricle and the mesencephalon, and ends in a thick, convex, free border. A sagittal section of the splenium shows that the posterior end of the corpus callosum is acutely bent forwards, the upper and lower parts being applied to each other.

The *superior surface* is convex from before backwards, and is about 2.5 cm. wide. Its medial part forms the bottom of the longitudinal fissure, and is in contact posteriorly with the lower border of the falx cerebri. Laterally it is overlapped by the cingulate gyrus, but is separated from it by the slit-like *callosal fissure*. It is traversed by numerous transverse ridges and furrows, and is covered by a thin layer of grey matter, the *supracallosal gyrus*, which exhibits on either side of the middle line the medial and lateral longitudinal striae already described (p. 813).

FIG. 778.—A scheme showing the relations of the ventricles to the surface of the brain.



The *inferior surface* is concave, and forms on either side of the middle line the roof of the lateral ventricle. Medially, this surface is attached in front to the septum pellucidum; behind this it is fused with the upper surface of the body of the fornix, while the splenium is in contact with the *tela chorioidea*.

On either side, the fibres of the corpus callosum radiate in the white substance and pass to the various parts of the cerebral cortex; those curving forward from the genu into the frontal lobe constitute the *forceps anterior*, and those curving backwards from the splenium into the occipital lobe, the *forceps posterior*. Between these two parts is the main body of the fibres; these constitute the *tapetum* and extend laterally on either side into the temporal lobe, and cover the central part of the lateral ventricle.

The lateral ventricles (fig. 778).—The two lateral ventricles are irregular cavities situated in the lower and medial parts of the cerebral hemispheres, one on either side of the middle line. They are separated from each other by a median vertical partition, the *septum pellucidum*, but communicate with the third ventricle and indirectly with each other through the *interventricular foramen*. They are lined by a thin, diaphanous membrane, the *ependyma*.

covered by ciliated epithelium, and contain cerebrospinal fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a *central part* or *body*, and three prolongations from it, termed *cornua* (figs. 779, 780).

FIG. 779.—A drawing of a cast of the ventricular cavities, viewed from above. (Retzius.)

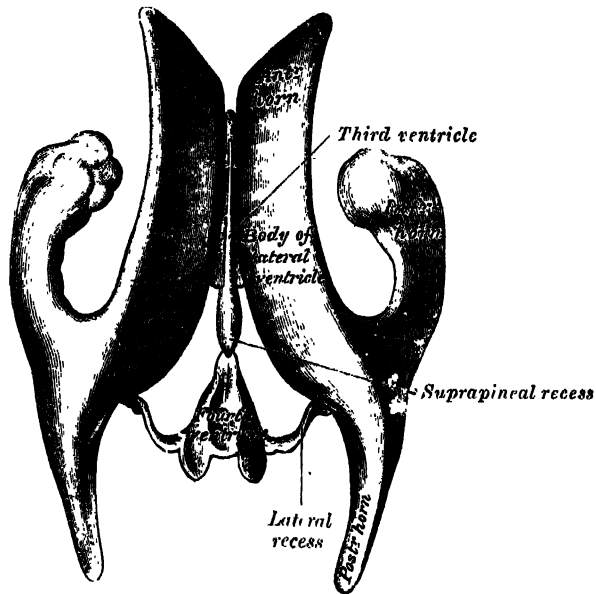
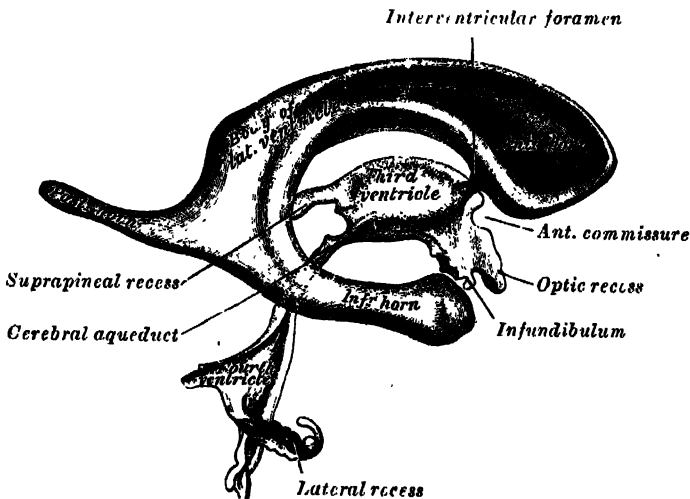


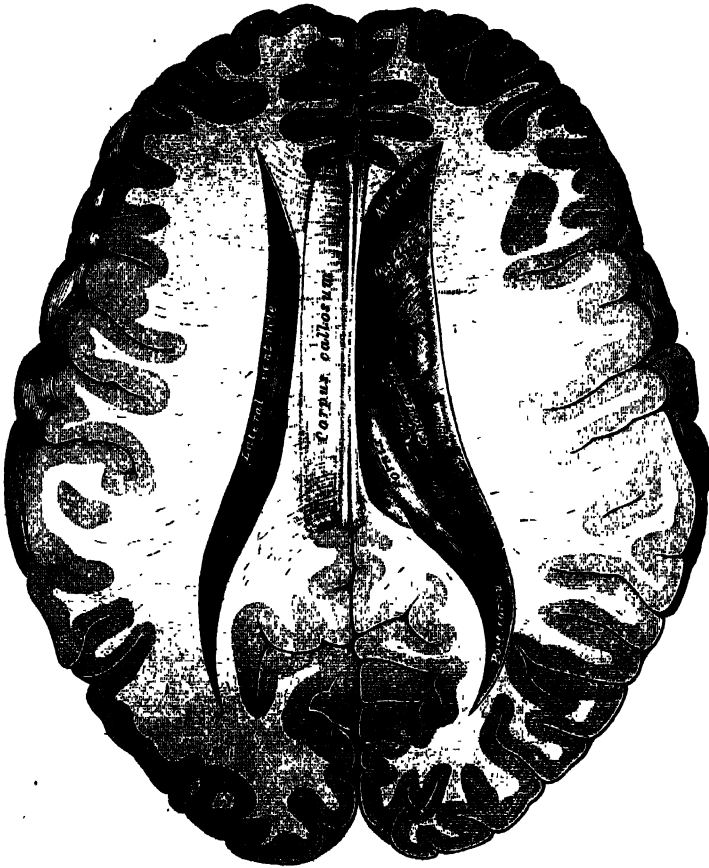
FIG. 780.—A drawing of a cast of the ventricular cavities, viewed from the side. (Retzius.)



The *central part* (fig. 781) of the lateral ventricle extends from the inter-ventricular foramen to the splenium of the corpus callosum. It is an irregularly curved cavity, triangular on transverse section, with a roof, a floor, and a medial wall. The roof is formed by the under surface of the corpus callosum; the floor, directed upwards and medialwards, by the following

parts, enumerated in their order of position from before backwards: the caudate nucleus of the corpus striatum, the stria terminalis and the terminal vein, the lateral portion of the upper surface of the thalamus, the choroid plexus, and the lateral part of the fornix; the medial wall is the posterior part of the septum pellucidum, which separates the ventricle from that of the opposite side.

FIG. 781.—The central parts and the anterior and posterior cornua of the lateral ventricles, exposed from above.



The anterior cornu (fig. 781) passes forwards and lateralwards, with a slight inclination downwards, from the interventricular foramen into the frontal lobe. It curves round the head of the caudate nucleus, and is bounded anteriorly by the posterior surface of the genu of the corpus callosum. In a coronal section it appears as a triangular slit below the anterior part of the corpus callosum. Its floor is convex, directed upwards and medialwards, and is formed by the head of the caudate nucleus. Its medial wall is vertical and consists of the septum pellucidum (p. 826).

The posterior cornu (figs. 781, 782) passes into the occipital lobe, its direction being backwards and lateralwards, and then medialwards. Its roof and lateral wall are formed by the fibres of the corpus callosum passing to the temporal and occipital lobes. On its medial wall is a longitudinal eminence, the *calcar avis*, which is an involution of the ventricular wall produced by the calcarine fissure. Above this the forceps posterior of the corpus callosum, sweeping round to enter the occipital lobe, causes another projection, termed the *bulb* of the posterior cornu. The calcar avis and bulb of the posterior

cornu are extremely variable in their degree of development; in some cases they are ill-defined, in others prominent.

FIG. 782.—A coronal section through the posterior cornu of the left lateral ventricle.

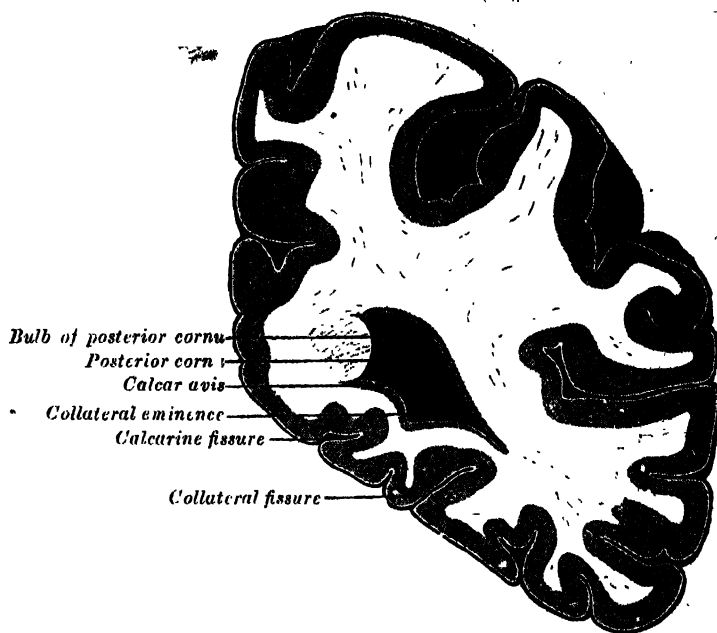
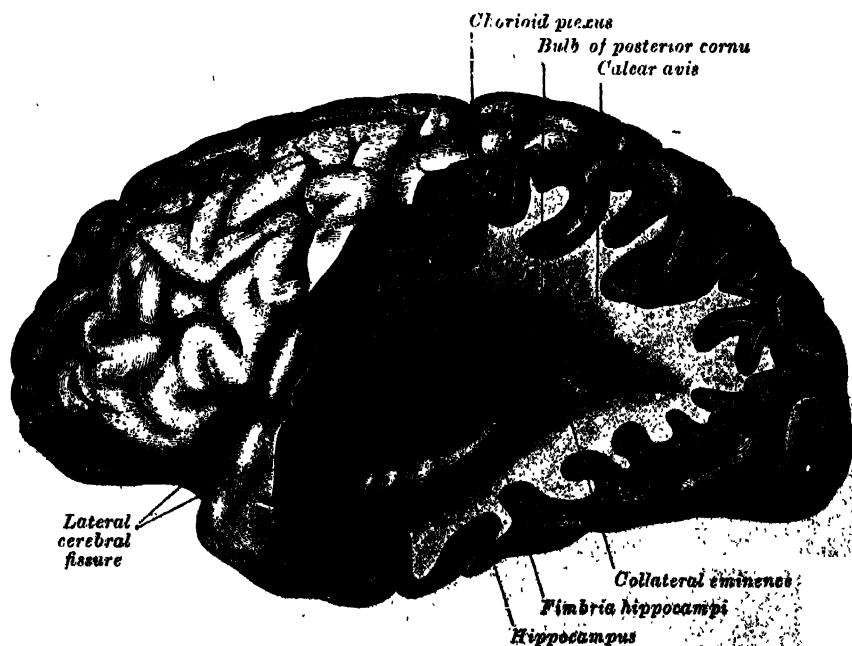


FIG. 783.—The posterior and inferior cornua of the left lateral ventricle, exposed from the side.



The inferior cornu (fig. 783), the largest of the three, traverses the temporal lobe, forming in its course a curve round the posterior end of the thalamus. It passes at first backwards, lateralwards, and downwards, and

then curves forwards to within 2.5 cm. of the apex of the temporal lobe, its position being fairly well indicated on the surface of the brain by the superior temporal sulcus. Its roof is formed chiefly by the inferior surface of the tapetum of the corpus callosum, but the tail of the caudate nucleus and the stria terminalis also extend forwards in the roof, at the extremity of which they end in a mass of grey substance, the *nucleus amygdalæ*. Its floor presents the following parts: the hippocampus, the fimbria hippocampi, the collateral eminence, and the chorioid plexus. When the chorioid plexus is removed, a cleft-like opening is left along the medial wall of the inferior cornu; this cleft constitutes the lower part of the chorioidal fissure.

The **hippocampus** (figs. 783, 784) is a curved eminence, about 5 cm. long, which extends throughout the entire length of the floor of the inferior cornu. Its lower end is enlarged, and presents two or three rounded elevations or digitations, which give it a paw-like appearance, and hence it is named the *pes hippocampi*. If a transverse section be made through the hippocampus, it will be seen that this eminence is produced by the folding of the wall of the hemisphere to form the hippocampal fissure. The main mass of the hippocampus consists of grey substance; but on its ventricular surface is a thin white layer, the *alveus*, which is continuous with the fimbria hippocampi.

The **collateral eminence** (fig. 784) is an elongated swelling lying lateral to and parallel with the hippocampus. It corresponds with the middle part of the collateral fissure, and its size depends on the depth and direction of this fissure. It is continuous behind with a flattened triangular area, the *trigonum collaterale*, situated between the posterior and inferior cornua.

The fimbria hippocampi is a continuation of the crus of the fornix, and will be discussed with that body; the chorioid plexus is described on p. 826.

The **corpus striatum** has received its name from the striped appearance which a section of its anterior part presents, in consequence of diverging white fibres being mixed with the grey substance which forms its chief mass. A part of the corpus striatum is imbedded in the white substance of the cerebral hemisphere, and is therefore external to the ventricle; it is termed the *extraventricular portion*, or the *lentiform nucleus*; the remainder, however, projects into the ventricle, and is named the *intraventricular portion*, or the *caudate nucleus* (fig. 785).

The **caudate nucleus** (fig. 781) is a pear-shaped, highly arched grey mass; its broad extremity, or *head*, is directed forwards into the anterior cornu of the lateral ventricle, and is continuous with the anterior perforated substance and with the anterior end of the lentiform nucleus; its narrow end, or *tail*, is directed backwards on the lateral side of the thalamus, from which it is separated by the stria terminalis and the terminal vein; it is then continued downwards into the roof of the inferior cornu, and ends in the *nucleus amygdalæ* at the apex of the temporal lobe. It is covered by the lining of the lateral ventricle, and crossed by some veins of considerable size. It is separated from the lentiform nucleus, in the greater part of its extent, by a thick lamina of white substance, called the *internal capsule*, but the two portions of the corpus striatum are united in front (figs. 786, 787).

The **lentiform nucleus** (lenticular nucleus) is lateral to the caudate nucleus and thalamus, and is seen only in sections of the hemisphere. When divided horizontally, it exhibits, to some extent, the appearance of a biconvex lens

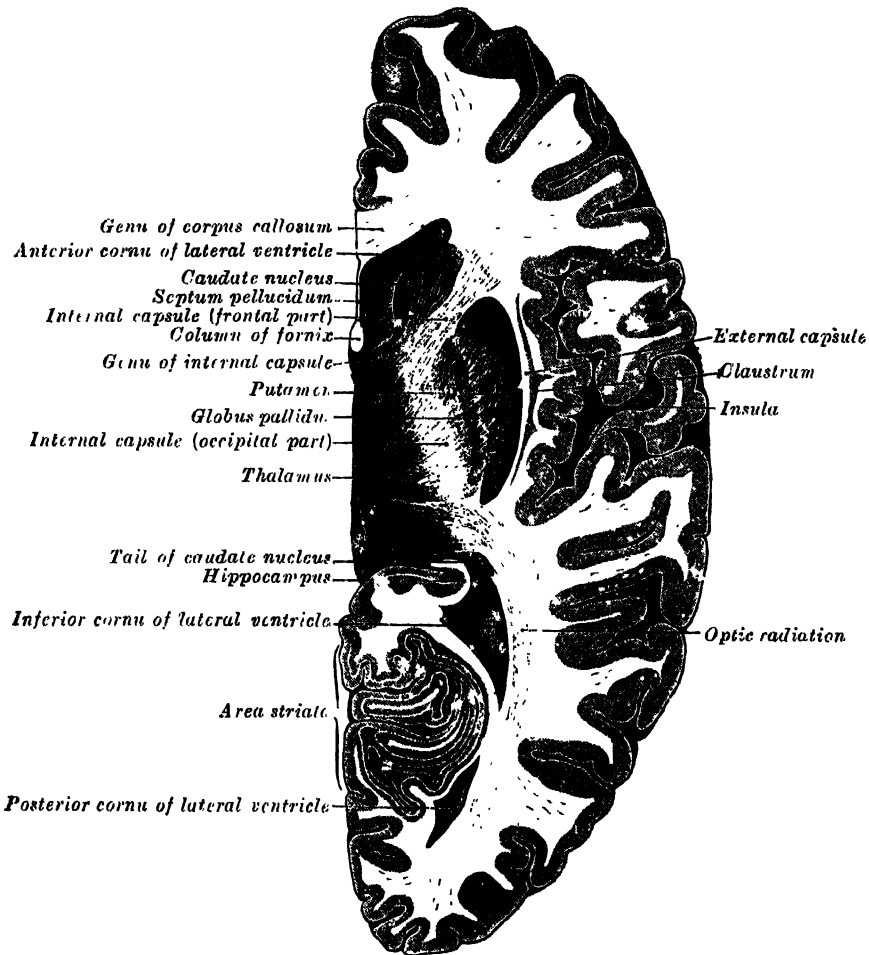
FIG. 784.—The inferior and posterior cornua of the left lateral ventricle, viewed from above.



(fig. 785), while a coronal section of its central part presents a somewhat triangular outline. It is shorter than the caudate nucleus and does not extend as far forwards. It is bounded laterally by a lamina of white substance called the *external capsule*, and lateral to this is a thin layer of grey substance termed the *claustrum*. Its anterior end is continuous with the lower part of the head of the caudate nucleus and with the anterior perforated substance.

In a coronal section through the middle of the lentiform nucleus, two *medullary laminae* are seen dividing it into three parts. The lateral and largest

FIG. 785.—A horizontal section of the right cerebral hemisphere.

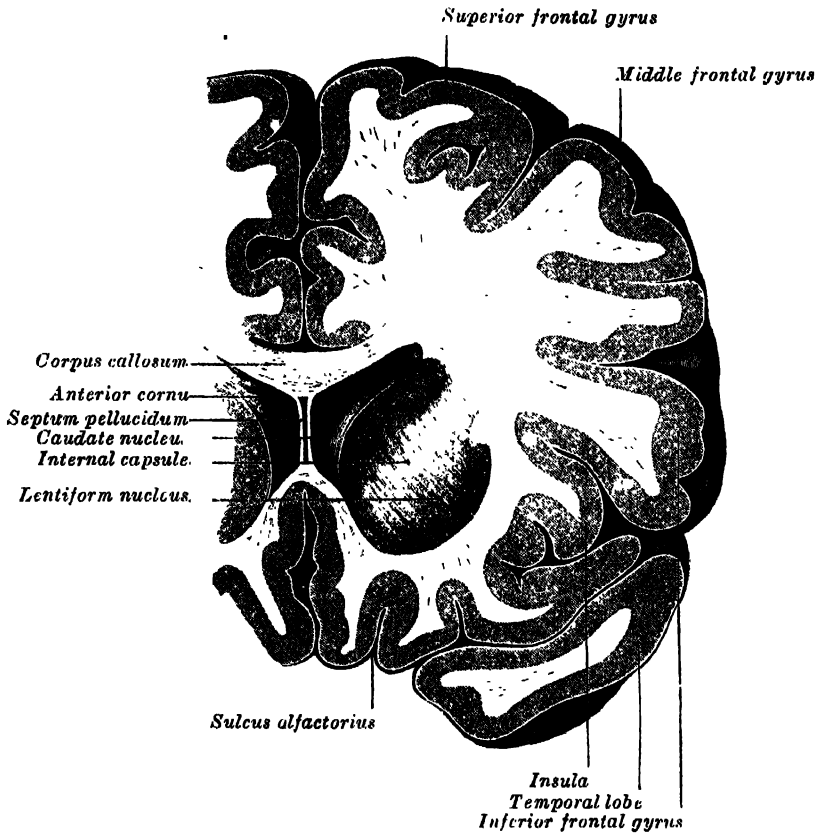


part is of a reddish colour, and is known as the *putamen*, while the medial and intermediate parts are of a yellowish tint, and together constitute the *globus pallidus*; all three are marked by fine radiating white fibres, which are most distinct in the putamen (fig. 787).

The grey substance of the corpus striatum is traversed by nerve-fibres, some of which originate in it. The cells are multipolar, both large and small; those of the lentiform nucleus contain yellow pigment. The caudate and lentiform nuclei are not only directly continuous with each other anteriorly, but are connected to each other by numerous fibres. The corpus striatum is also connected: (1) to the cerebral cortex, by the *corticostriate* fibres; (2) to the thalamus, by fibres which pass through the internal capsule, and by a strand named the *ansa lentiformis*; (3) to the cerebral peduncle, by fibres which leave the lower parts of the caudate and lentiform nuclei.

The **claustrum** (figs. 785, 787) is a thin layer of grey substance, situated on the lateral surface of the external capsule. In a coronal section it is seen to be triangular in shape, with the apex directed upwards. Its medial surface, contiguous to the external capsule, is smooth, but its lateral surface presents ridges and furrows corresponding with the gyri and sulci of the insula, with which it is in close relationship. The claustrum is regarded as a detached portion of the grey substance of the insula, from which it is separated by a layer of white fibres, the *capsula extrema* or *band of Baillarger*. Its cells are small and spindle-shaped and contain yellow pigment; they are similar to those of the deepest layer of the cortex.

FIG. 786.—A coronal section through the anterior cornua of the lateral ventricles.



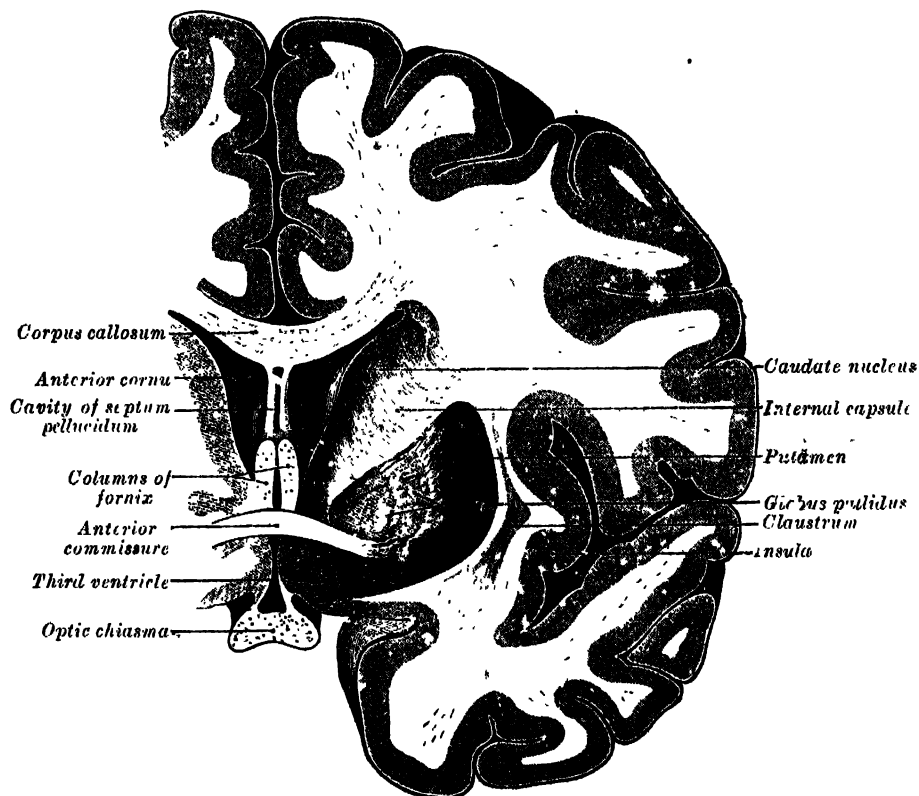
The **nucleus amygdalæ** is an ovoid grey mass, situated at the lower end of the roof of the inferior cornu. It is merely a localised thickening of the grey cortex, continuous with that of the uncus; in front it is continuous with the putamen, behind with the stria terminalis and the tail of the caudate nucleus.

The **internal capsule** (fig. 788) is a flattened band of white fibres, between the lentiform nucleus on the lateral side and the caudate nucleus and thalamus on the medial side. In horizontal section (fig. 785), it is seen to be somewhat abruptly curved, with its convexity directed medialwards; the prominence of the curve is called the *genu*, and projects between the caudate nucleus and the thalamus. The portion in front of the genu is termed the *frontal part*, and separates the lentiform from the caudate nucleus; the portion behind the genu is the *occipital part*, and separates the lentiform nucleus from the thalamus.

The *frontal part* of the internal capsule contains: (1) fibres running from the thalamus to the frontal lobe; (2) fibres joining the lentiform and caudate nuclei; (3) fibres connecting the cortex with the corpus striatum; and (4) fibres

passing from the frontal lobe through the medial fifth of the base of the cerebral peduncle to the nuclei pontis. The fibres in the region of the genu are named the *geniculate fibres*; they originate in the motor part of the cerebral cortex, and, after passing downwards through the base of the cerebral peduncle with the cerebrospinal fibres, undergo decussation and end in the motor nuclei of the cerebral nerves of the opposite side. The anterior two-thirds of the occipital part of the internal capsule contains the *cerebrospinal fibres*, which arise in the motor area of the cerebral cortex, and passing downwards through the middle three-fifths of the base of the cerebral peduncle, are continued into

FIG. 787.—A coronal section of the brain through the anterior commissure.



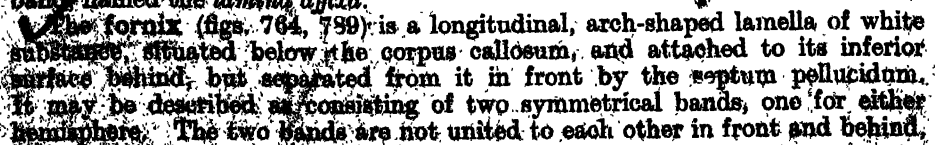
the pyramids of the medulla oblongata. The posterior third of the occipital part contains: (1) sensory fibres, largely derived from the thalamus, though some may be continued upwards from the medial lemniscus; (2) the fibres of the optic radiation, from the lower visual centres to the cortex of the occipital lobe; (3) acoustic fibres, from the lateral lemniscus to the temporal lobe; and (4) fibres which pass from the occipital and temporal lobes to the nuclei pontis.

The fibres of the internal capsule radiate widely as they pass to and from the various parts of the cerebral cortex, forming the *corona radiata* (fig. 785) and intermingling with the fibres of the corpus callosum.

The *external capsule* (fig. 785) is a lamina of white substance, situated laterally to the lentiform nucleus, between it and the claustrum, and continuous with the internal capsule below and behind the lentiform nucleus. It probably contains fibres derived from the thalamus, the anterior commissure, and the subthalamic region.

The *substantia innominata* of Meynert is a stratum consisting of grey and white substance, which lies below the anterior part of the thalamus and

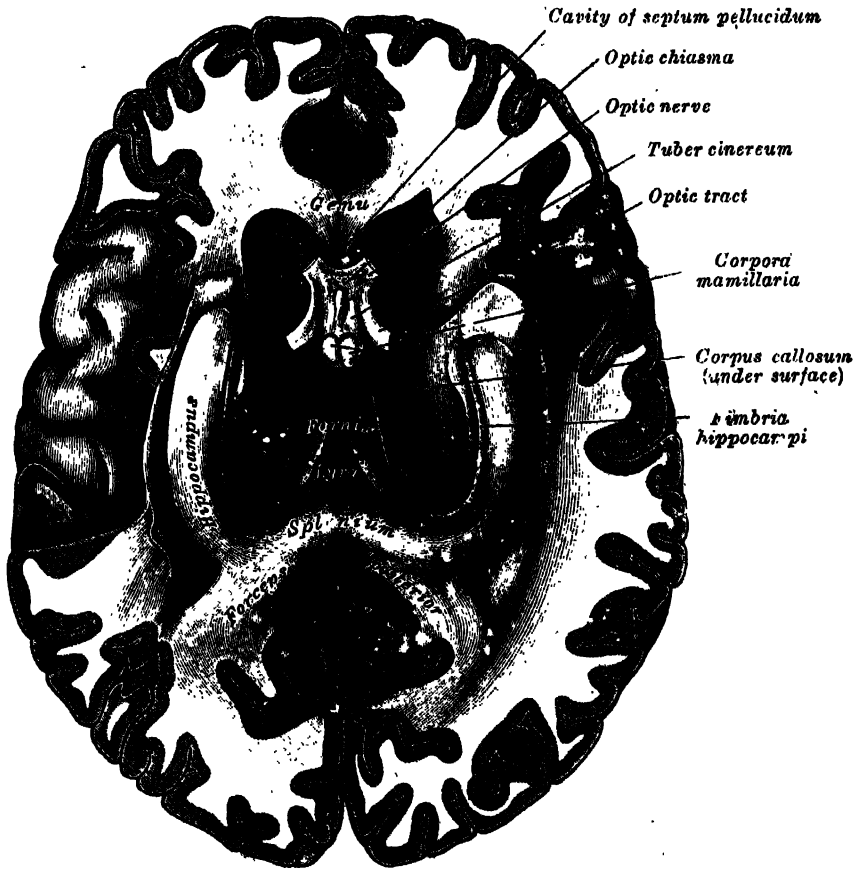
FIG. 788.—A dissection showing the course of the cerebrospinal fibres.
(E. B. Jamieson.)



but their central parts are joined together in the middle line. The anterior parts are called the columns of the fornix; the intermediate united portions, the body; and the posterior parts, the crura.

The *body* of the fornix is triangular, narrow in front, and broad behind. The medial part of its upper surface is connected to the septum pellucidum in front and to the corpus callosum behind. The lateral portion of this surface forms part of the floor of the lateral ventricle, and is covered by the ventricular epithelium. Its thin lateral edge overlaps the chorioid plexus, and is continuous with the epithelial covering of this structure. The under surface

FIG. 789.—The fornix and the corpus callosum, from below. (From a specimen in the Department of Human Anatomy of the University of Oxford.)



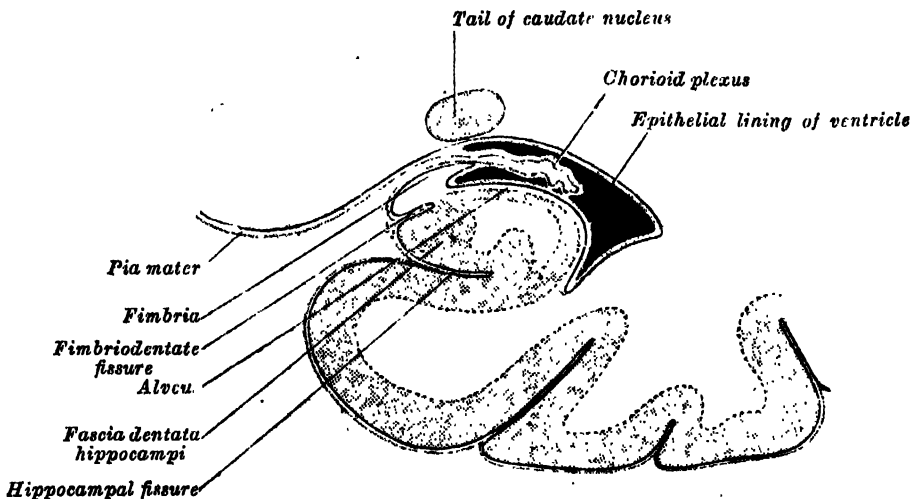
rests upon the tela chorioidea of the third ventricle or velum interpositum, which separates it from the epithelial roof of the third ventricle, and from the medial portions of the upper surfaces of the thalami. The lateral portions of the body of the fornix are joined inferiorly by a thin triangular lamina, named the *psalterium* or *lyra*. This lamina contains some transverse fibres which connect the two hippocampi across the middle line and constitute the *hippocampal commissure*. Between the psalterium and the corpus callosum a horizontal cleft, the so-called *ventricle of the fornix* or *ventricle of Verga*, is sometimes found.

The *columns* (anterior pillars) of the fornix arch downwards in front of the thalamus and behind the anterior commissure, and form the anterior boundary of the interventricular foramen; each descends through the grey substance in the lateral wall of the third ventricle to the base of the brain, where it ends in the corpus mamillare. From the cells of the corpus mamillare

the *thalamomamillary fasciculus* (bundle of Vieq d'Azyr) takes origin and is prolonged into the anterior nucleus of the thalamus. The column of the fornix and the thalamomamillary fasciculus together form a loop resembling the figure 8, but the continuity of the loop is broken in the corpus mamillare. The column of the fornix is joined by the stria medullaris of the pineal body and by the superficial fibres of the stria terminalis; it is said also to receive fibres from the septum pellucidum. Zuckerkandl describes an *olfactory fasciculus* which becomes detached from the main portion of the column of the fornix, and passes downwards in front of the anterior commissure to the base of the brain, where it divides into two bundles: one joins the medial stria of the olfactory tract; the other joins the subcallosal gyrus, and through it reaches the hippocampal gyrus.

The *crura* (posterior pillars) of the fornix are prolonged backwards from the body. They are flattened bands, and at their commencement are intimately connected with the under surface of the corpus callosum. Diverging from

FIG. 790.—A coronal section of the inferior cornu of the lateral ventricle. (Diagrammatic.)



one another, each curves round the posterior end of the thalamus, and passes downwards and forwards into the inferior cornu of the lateral ventricle. (figs. 784, 789). Here it lies along the concavity of the hippocampus, on the surface of which some of its fibres are spread out to form the *alveus*, while the remainder are continued as a narrow white band, the *fimbria hippocampi*, which is prolonged into the uncus of the hippocampal gyrus. The inner edge of the fimbria overlaps the fascia dentata hippocampi (dentate gyrus) (p. 813), from which it is separated by the *fimbriodentate fissure*; from its lateral, thin edge the ventricular epithelium is reflected over the chorioid plexus as the latter projects into the chorioidal fissure.

Interventricular foramen (foramen of Monroe).—Between the columns of the fornix and the anterior ends of the thalami, an oval aperture is present on either side: this is the interventricular foramen, and through it the lateral ventricles communicate with the third ventricle. Behind the epithelial lining of the foramen the chorioid plexuses of the lateral ventricles are joined across the middle line.

The anterior commissure is a bundle of white fibres, connecting the two cerebral hemispheres across the middle line, and placed in front of the columns of the fornix. On sagittal section it is oval in shape, its long diameter being vertical and measuring about 5 mm. Its fibres can be traced lateralwards and backwards on either side beneath the corpus striatum into the substance of the temporal lobe. It connects the two temporal lobes, and also contains decussating fibres from the olfactory tracts.

The *septum pellucidum* (fig. 764) is a thin, vertically placed partition consisting of two laminae, separated in the greater part of their extent by a narrow chink or interval, the *cavity of the septum pellucidum*. It is attached, above, to the under surface of the corpus callosum; below, to the anterior part of the fornix behind, and the reflected portion of the corpus callosum in front. It is triangular in form, with its base in front; its inferior angle corresponds with the upper part of the anterior commissure. The lateral surface of each lamina is directed towards the body and anterior cornu of the lateral ventricle, and is covered by the ependyma of that cavity.

FIG. 791.—The tela chorioidea of the third ventricle, and the chorioid plexus of the left lateral ventricle, exposed from above.



The *cavity of the septum pellucidum* is generally regarded as part of the longitudinal cerebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum therefore forms part of the medial wall of the hemisphere, and consists of a medial layer of grey substance derived from that of the cortex, and a lateral layer of white substance continuous with that of the cerebral hemispheres. This cavity is not developed from the cavity of the cerebral vesicles, and never communicates with the ventricles of the brain.

The chorioid plexus of the lateral ventricle (fig. 791) is a highly vascular, fringe-like process of pia mater, which projects into the ventricular cavity. The plexus, however, is everywhere covered by a layer of epithelium continuous with the epithelial lining of the ventricle. It extends from the interventricular foramen, where it is joined with the plexus of the opposite

ventricle, to the end of the inferior cornu. The part in relation to the body of the ventricle forms the vascular fringed margin of a triangular process of pia mater, named the tela chorioidea of the third ventricle, and projects from under cover of the lateral edge of the fornix. It lies upon the upper surface of the thalamus, from which the ventricular epithelium is reflected over the plexus on to the edge of the fornix (fig. 768). The portion in relation to the inferior cornu lies in the concavity of the hippocampus and overlaps the fimbria hippocampi; from the lateral edge of the fimbria the epithelium is reflected over the plexus on to the roof of the cornu (fig. 790).

The chorioid plexus consists of minute and highly vascular villous processes, each with an afferent and an efferent vessel. The *arteries* of the plexus are: (a) the anterior chorioid, a branch of the internal carotid artery, which enters the plexus at the end of the inferior cornu; and (b) the posterior chorioid, one or two small branches of the posterior cerebral artery, which pass forwards under the splenium. The *veins* of the plexus unite to form a tortuous vein, which courses from behind forwards to the interventricular foramen and there joins with the terminal vein (p. 680) to form the corresponding internal cerebral vein.

When the chorioid plexus is pulled away, the continuity between its epithelial covering and the epithelial lining of the ventricle is severed, and a cleft-like space is produced. This is named the *chorioid fissure*; like the plexus, it extends from the interventricular foramen to the end of the inferior cornu. The upper part of the fissure, i.e. the part nearest the interventricular foramen, is situated between the lateral edge of the fornix and the upper surface of the thalamus; farther back, at the beginning of the inferior cornu, it is between the commencement of the fimbria hippocampi and the posterior end of the thalamus, while in the inferior cornu it lies between the fimbria in the floor and the stria terminalis in the roof of the cornu.

The tela chorioidea of the third ventricle (*velum interpositum*) (fig. 791) is a double fold of pia mater, triangular in shape, which lies beneath the fornix. The lateral portions of its lower surface rest upon the thalami, while the medial portion of this surface is in contact with the epithelial roof of the third ventricle. Its apex is situated at the interventricular foramen; its base corresponds with the splenium of the corpus callosum, and occupies the interval between that structure above and the corpora quadrigemina and pineal body below. This interval, together with the lower portions of the chorioid fissures, is sometimes spoken of as the *transverse fissure* of the brain. The two layers of the tela separate from each other at the base, and are continuous with the pia mater investing the brain in this region. Its lateral margins are modified to form the highly vascular chorioid plexuses of the lateral ventricles. It is supplied by the anterior and posterior chorioid arteries already described. The veins of the tela chorioidea are named the internal cerebral veins (*venæ Galeni*); they are two in number, and run backwards between its layers, each being formed at the interventricular foramen by the union of the terminal vein with the chorioid vein. The internal cerebral veins unite posteriorly in a single trunk, the great cerebral vein (*vena magna Galeni*), which curves backwards and upwards behind the splenium of the corpus callosum and ends in the straight sinus.

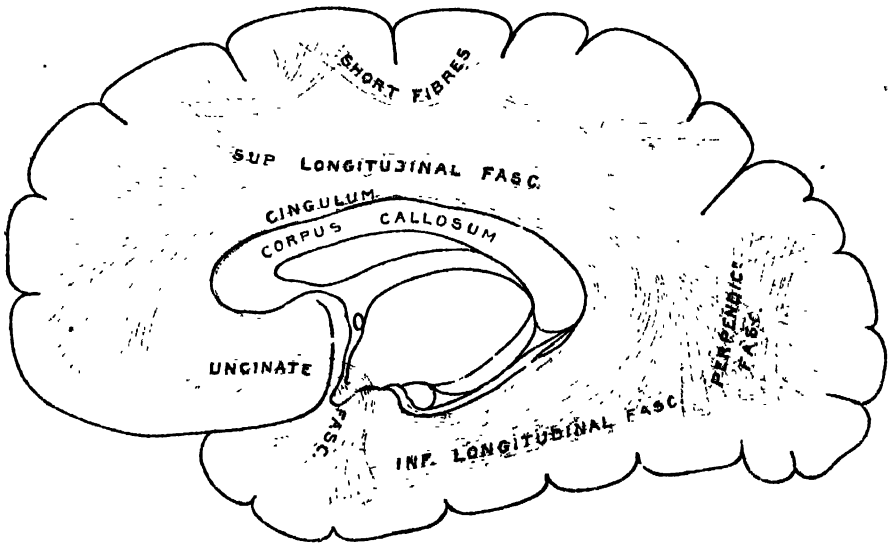
STRUCTURE OF THE CEREBRAL HEMISPHERES

The cerebral hemispheres are composed of grey and white substance: the former covers their surfaces, and is termed the *cortex*; the latter occupies the interior of the hemispheres.

The white substance consists of medullated fibres, varying in size, and arranged in bundles supported by neuroglia. The fibres may be divided, according to their course and connexions, into three systems. 1. Projection fibres connect the hemisphere with the lower parts of the brain and with the medulla spinalis. 2. Transverse or commissural fibres unite the two hemispheres. 3. Association fibres connect different structures in the same hemisphere; these are, in many instances, collateral branches of the projection fibres, but others are the axons of independent cells.

1. The **projection fibres** consist of efferent and afferent fibres uniting the cortex with the lower parts of the brain and with the medulla spinalis. The principal efferent strands are : (1) the motor tract, occupying the genu and anterior two-thirds of the occipital part of the internal capsule, and consisting of (a) the geniculate fibres, which decussate and end in the motor nuclei of the cerebral nerves of the opposite side ; and (b) the cerebrospinal fibres, which are prolonged through the pyramid of the medulla oblongata into the medulla spinalis ; (2) the corticopontine fibres, ending in the nuclei pontis. The chief afferent fibres are : (1) those of the brachia conjunctiva cerebelli which are not interrupted in the red nucleus and thalamus ; (2) numerous fibres arising within the thalamus, and passing through its stalks to the different parts of the cortex (p. 796) ; (3) optic and acoustic fibres, the former passing to the occipital, the latter to the temporal lobe.

FIG. 792.—A diagram showing the principal systems of association fibres in the cerebrum.



2. The **transverse or commissural fibres** connect the two hemispheres. They include : (a) the transverse fibres of the corpus callosum, (b) the anterior commissure, (c) the posterior commissure, and (d) the lyra or hippocampal commissure ; they have already been described.

3. The **association fibres** (fig. 792) unite different parts of the same hemisphere, and are of two kinds : (1) *short association fibres* connecting adjacent gyri ; (2) *long association fibres* passing between more distant parts.

The *short association fibres* lie immediately beneath the grey substance of the cortex of the hemispheres, and connect adjacent gyri.

The *long association fibres* include the following : (a) the uncinat fasciculus ; (b) the cingulum ; (c) the superior longitudinal fasciculus ; (d) the inferior longitudinal fasciculus ; (e) the perpendicular fasciculus ; (f) the occipito-frontal fasciculus ; and (g) the fornix.

(a) The *uncinate fasciculus* passes across the bottom of the lateral cerebral fissure, and unites the gyri of the frontal lobe with the anterior end of the temporal lobe.

(b) The *cingulum* is contained within the cingulate gyrus. Beginning in front at the anterior perforated substance, it passes forwards and upwards parallel with the rostrum, winds round the genu, runs backwards above the body of the corpus callosum, turns round the splenium, and ends in the hippocampal gyrus.

(c) The *superior longitudinal fasciculus* passes backwards from the frontal lobe above the lentiform nucleus and insula ; some of its fibres end in the

occipital lobe, and others curve downwards and forwards into the temporal lobe.

(d) The *inferior longitudinal fasciculus* connects the temporal and occipital lobes, running along the lateral walls of the inferior and posterior cornua of the lateral ventricle.

(e) The *perpendicular fasciculus* runs vertically through the front part of the occipital lobe, and connects the inferior parietal lobule with the fusiform gyrus.

(f) The *occipitofrontal fasciculus* passes backwards from the frontal lobe, along the lateral border of the caudate nucleus, and on the medial aspect of the corona radiata; its fibres radiate in a fan-like manner and pass into the occipital and temporal lobes laterally to the posterior and inferior cornua. Dejerine regards the fibres of the tapetum as being derived from this fasciculus, and not from the corpus callosum.

(g) The *fornix* connects the hippocampal gyrus with the corpus mamillare, and, by means of the thalamomamillary fasciculus, with the thalamus (p. 825). Through the fibres of the hippocampal commissure it probably also unites the right and left hippocampal gyri.

The grey substance of the hemisphere is divided into: (1) that of the cerebral cortex, and (2) that of the caudate nucleus, the lentiform nucleus, the claustrum, and the nucleus amygdalæ.

STRUCTURE OF THE CEREBRAL CORTEX (fig. 793)

The cerebral cortex differs in thickness and structure in different parts of the hemisphere. It is thinner in the occipital region than in the anterior and posterior central gyri, and it is also much thinner at the bottom of the sulci than on the top of the gyri.

The cortex is made up of nerve-cells of varying size and shape, and of nerve-fibres which are either medullated or naked axis-cylinders, imbedded in a matrix of neuroglia. According to J. S. Bolton, it exhibits five layers:

1. The outer fibre-lamina (molecular or plexiform layer).
2. The outer cell-lamina.
3. The middle cell-lamina (layer of granules).
4. The inner fibre-lamina (inner band of Baillarger).
5. The inner cell-lamina (polymorphous layer).

1. The *outer fibre-lamina*.—The superficial part of this layer consists of a stratum of medullated nerve-fibres (plexus of Exner), running parallel with the surface. The deeper part is largely composed of the dendrites of cells from the subjacent laminae. It contains also a few nerve-cells, and the terminations of fibres which run into the cortex from the white substance of the hemisphere. The cells are of two kinds: (1) small irregular cells with a varying number of dendrites and short axons; (2) fusiform cells with their long axes parallel with the surface; the dendrites and the axons of the latter run horizontally, and the axons give off numerous collaterals. The distribution of the axons of both types of cell is limited to the outer fibre-lamina.

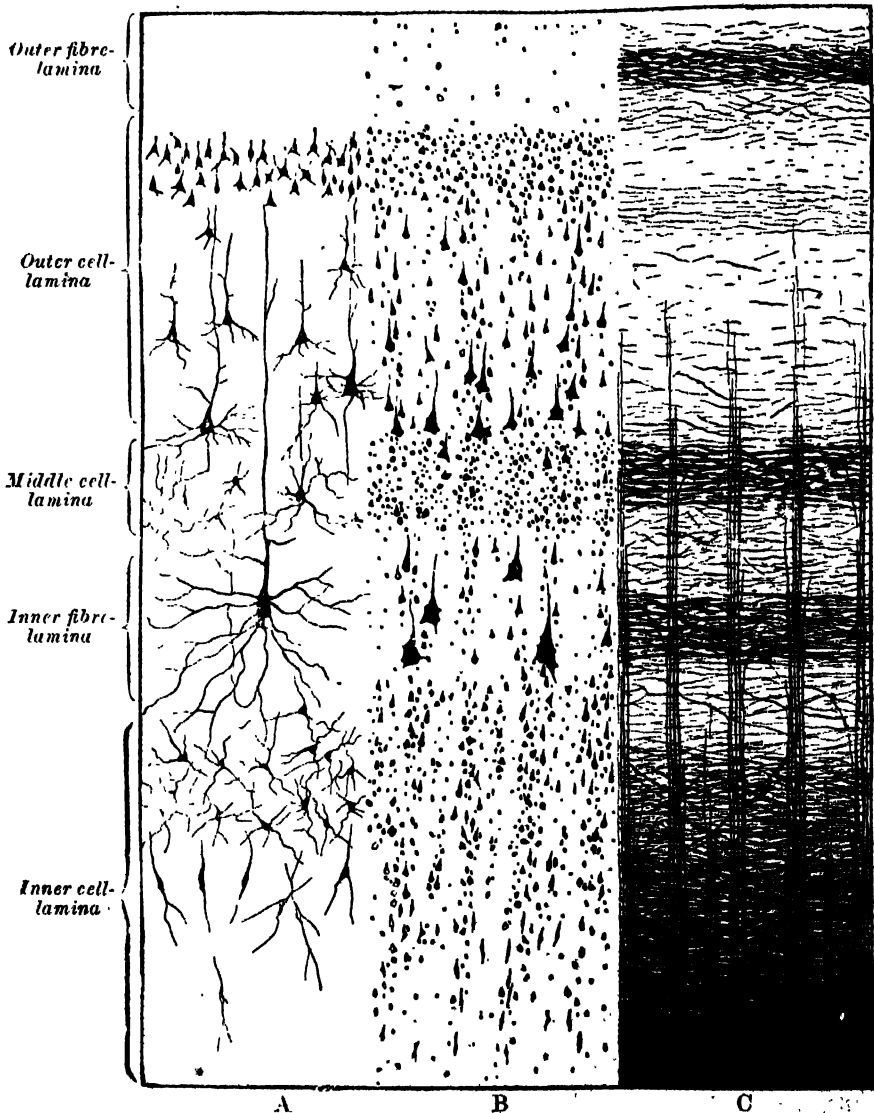
2. The *outer cell-lamina* contains a large number of pyramidal nerve-cells which are small (10μ to 15μ in length) in the superficial part, but large (20μ to 30μ) in the deep part of the lamina. Each pyramidal cell contains granular pigment and a large round or oval nucleus, and the apex of the cell is directed towards the surface. The axon arises from the base of the cell, and runs into the central white substance, giving off collaterals in its course, and being distributed as a projection, association, or commissural fibre. The apical and basal parts of the cell give off dendrites; the apical dendrite ends in the molecular layer by dividing into numerous branches, all of which may be seen, when stained by the silver or methylene blue method, to be studded with bristle-like processes.

3. The *middle cell-lamina* or layer of granules consists chiefly of small stellate cells, but some pyramidal cells are also present in its deepest part. The axons of the stellate cells run a short course, and terminate either in the same layer or in the outer cell-lamina. The axons of some of the pyramidal cells descend for a short distance and then turn back and end in the outer

cell-lamina; the axons of others run into the central white substance. In this lamina a well-marked stratum of nerve-fibres (*external band of Baillarger*) runs parallel with the cortex.

The middle cell-lamina is especially developed in the occipital lobe (visuo-sensory area), where it consists of two layers which are separated by the layer of white nerve-fibres, which is here named the *band of Gennari*.

FIG. 798.—A diagram to show the layers of cells and fibres in the grey substance of the cortex of the human cerebral hemisphere, according to the histological methods of Golgi, Nissl and Weigert. From Luciani's Physiology (Macmillan & Co., Ltd.).



4. The inner fibre-lamina is composed of medullated nerve-fibres running parallel with the surface, and forming the *internal band of Baillarger*. In the anterior central gyrus and in the paracentral lobule it contains large pyramidal cells, the *giant-cells of Betz*, which are often solitary, but may occur in groups of three to five. These cells may be 50μ in length and 40μ in breadth; in the paracentral lobule they may attain a length of 65μ .

5. The inner cell-lamina or polymorphous layer contains cells of various

shapes—fusiform, oval, triangular, or stellate. Their dendrites are directed outwards, but do not reach the molecular layer; most of their axons pass into the subjacent white substance. The axons of a few of these cells (cells of Golgi's second type) are short, and terminate in the adjacent grey substance. The cells of *Martinotti* in the inner cell-lamina are pyramidal in shape with their bases directed towards the surface; their dendrites are short, and their axons pass out into the outer fibre-lamina, where they form an extensive horizontal arborisation.

In addition to the bands of medullated fibres described above as running parallel with the surface (*tangential fibres*), two other tangential bands occur, the *band of Bechterew* in the outer cell-lamina, and the deep tangential fibres in the lower part of the inner cell-lamina. The tangential fibres consist of (a) the collaterals of the axons of the pyramidal and polymorphous cells, and of the cells of *Martinotti*; (b) the branching axons of Golgi's cells; (c) the collaterals and terminal arborisations of the projection, commissural, and association fibres. *Radial fibres* also occur in the cortex and are, on the one hand, the axons of the pyramidal and polymorphous cells descending into the white substance, and, on the other, the terminations of projection, commissural, or association fibres, ascending to end in the cortex. The axons of the cells of *Martinotti* are also ascending fibres.

Development of the laminae of the cortex.—The inner cell-lamina is the first to appear in the course of development, and in the sixth month of foetal life it has attained three-fourths of its adult depth. The inner fibre-lamina is associated with the inner cell-lamina, and although it does not appear until the sixth month of foetal life, it reaches its adult depth very quickly. The middle cell-lamina can be distinguished in the sixth month of foetal life; at this period it is one-half, and at birth three-fourths of the depth which it finally attains. The outer cell-lamina is the last to develop, both ontogenetically and phylogenetically, and its depth varies with the intellectual capacity of the individual. The outer fibre-lamina is well developed at birth, and its further growth is associated with that of the outer cell-lamina.

SPECIAL TYPES OF CEREBRAL CORTEX

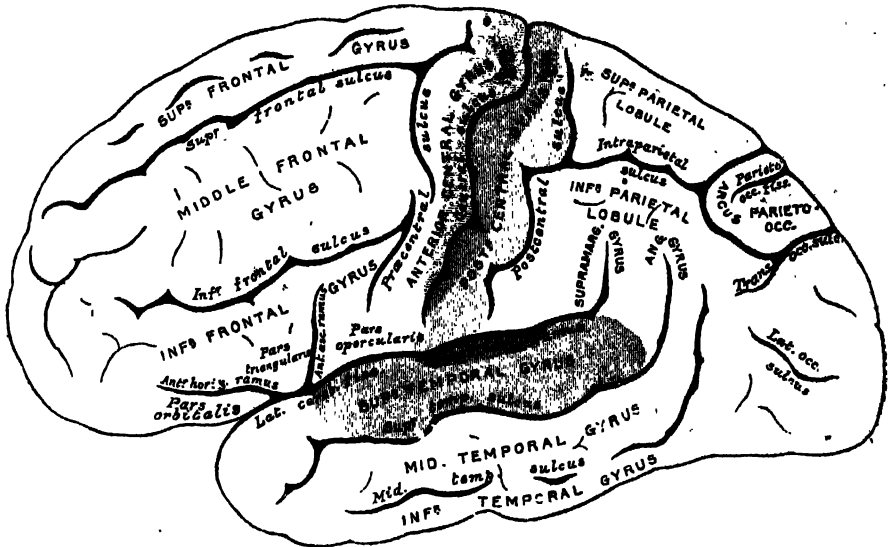
The histological investigations of Bevan Lewis, Bolton, Campbell, and Brodmann, the embryological researches of Flechsig, and the experimental work of Sherrington and many others, have shown that the cortex of the cerebral hemispheres can be mapped out into areas which possess different functions, and that the minute structure of the cortex varies characteristically in these different areas. The anterior central gyrus (motor area), the convolutions bounding the calcarine fissure (visuosensory area), the prefrontal district (associational area), and the hippocampal gyrus may be taken as types.

The **motor area** (figs. 794, 795) is characterised by the presence of the giant-cells of Betz in the inner fibre-lamina, and by the absence or very slight development of the middle cell-lamina. Physiological investigations show that the centres for the lower limb are located on the highest part of the anterior central gyrus and its continuation on to the paracentral lobule; those for the trunk are on the upper portion, and those for the upper limb on the middle portion of the anterior central gyrus. The facial centres are situated on the lower part of the same gyrus, those for the tongue, larynx, muscles of mastication, and pharynx on the frontal operculum, while those for the head and neck occupy the posterior end of the middle frontal gyrus.

The **visuosensory area** (figs. 794, 795) is distinguished by the presence of the band of Gennari superficial to the middle cell-lamina and a second layer of granules between the band of Gennari and the outer cell-lamina. When blindness exists, the band of Gennari and the layers of granules superficial to it are diminished in depth, the former by as much as 50 per cent. in old-standing cases of optic atrophy. During development the visuosensory area matures rapidly; its outer cell-lamina develops early, but in the adult is only five-ninths of the depth of the same layer in the prefrontal region.

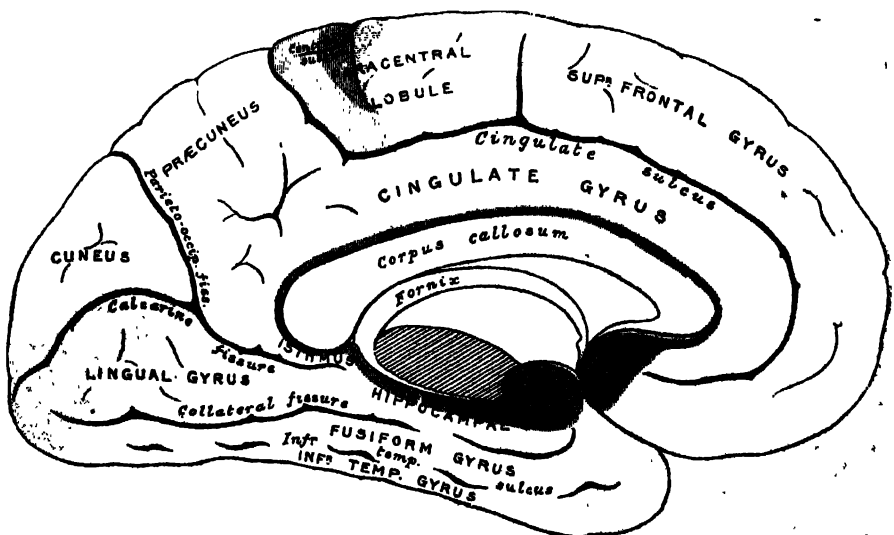
The visuosensory area is surrounded by a zone 1 cm. or more in breadth, known as the **visuopsychic area**. In this zone the outer superadded layer of granules suddenly ceases, and the outer cell-lamina is more developed. In infants one

FIG. 794.—The areas of localisation on the lateral surface of the left cerebral hemisphere



Motor area in red. Area of general sensations in blue. Auditory area in green. Visual area in yellow. The psychic portions are in lighter tints.

FIG. 795.—The areas of localisation on the medial surface of the left cerebral hemisphere.



Motor area in red. Area of general sensations in blue. Visual area in yellow. Olfactory area in purple. The psychic portions are in lighter tints.

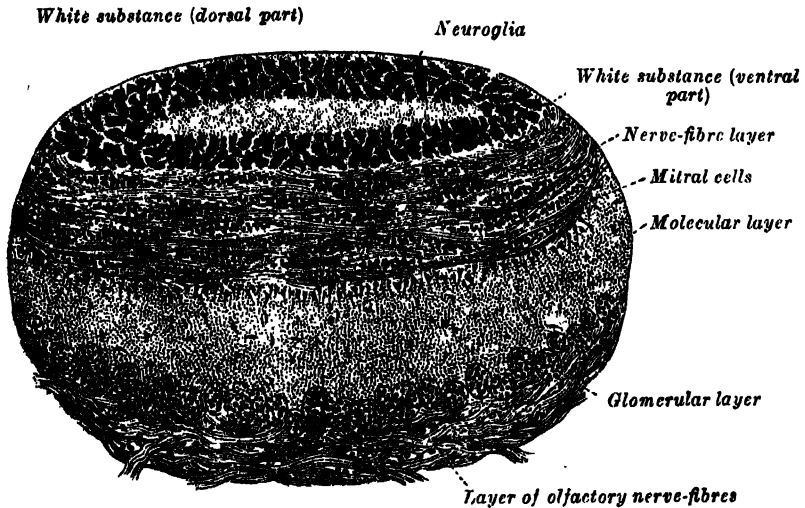
month old the outer cell-lamina is two-thirds, and at the age of three months it is three-fourths, of the adult depth. The structure of the visuopsychic area is not modified by blindness.

The minute structure of the other sensory areas of the cortex resembles that of the visual area. These other sensory areas are as follows: the **auditory area** occupies the middle third of the superior temporal gyrus and

the adjacent gyri in the lateral cerebral fissure; the auditopsychic area is a zone surrounding the auditosensory area and has not been exactly defined; the area for the *sense of taste* is probably in the uncus and hippocampal gyrus; that for the *sense of smell* is the rhinencephalon; the area for *heat, cold, and pain* is somewhat diffuse, but the areas for the *tactile* and *muscular senses* are located mainly in the posterior central gyrus (fig. 794).

The associational areas are three in number: (1) the prefrontal, (2) an area occupying the posterior portions of the temporal and parietal lobes, and (3) the insula. The prefrontal associational area is especially characteristic of the human brain, and it may be taken as the type. It is distinguished by the great development of the outer cell-lamina; the cells of this lamina are undifferentiated in the sixth month of foetal life, and the lamina is only one-fourth of the adult depth; it is the only layer which varies appreciably in depth in normal brains, and it is under-developed in idiots and imbeciles; it is the last to be evolved and the first to retrogress (Bolton). A special

FIG. 796.—A coronal section of the olfactory bulb. (Schwalbe.)



feature of the insula is the detachment of the polymorphous layer which is known as the claustrum (p. 821); the capsula extrema is a greatly thickened inner line of Baillarger.

The minute structure of the hippocampus, the fascia dentata, and the olfactory bulb calls for special description.

In the hippocampus the white substance is represented by a layer termed the *alveus* which lies next the ventricular ependyma. The grey substance consists of: (1) a layer of large pyramidal cells next the alveus; (2) a layer occupied by the apical dendrons of the pyramidal cells, and called the *stratum radiatum*; (3) a molecular layer, the deeper part of which, called the *stratum lacunosum*, exhibits interlacing fibres and dendrites, and contains numerous small, angular nerve-cells; near the dentate gyrus there is a layer of small cells, internal to the stratum lacunosum, known as the *stratum granulosum*.

In the fascia dentata hippocampi (dentate gyrus) the molecular layer contains some pyramidal cells, while the layer of pyramidal cells is almost entirely represented by small ovoid cells.

The olfactory bulb.—In many animals the olfactory bulb contains a cavity which communicates through the olfactory tract with the lateral ventricle. In man the original cavity is filled by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal aspect. Its dorsal part contains a small amount of grey and white substance, but this is scanty and ill-defined. A section through the ventral part (fig. 796) shows it to consist of the following layers from without inwards: (1) A layer of olfactory nerve-fibres;

these fibres are the non-medullated axons prolonged from the olfactory cells of the nasal cavity, and reach the bulb by passing through the lamina cribrosa of the ethmoidal bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrites of the mitral cells, presently to be described. (2) Glomerular layer.—This contains numerous spheroidal bodies, termed *glomeruli*, each of which is produced by the branching and interlacement of the terminations of one or more olfactory nerve-fibres with the descending dendrite of a mitral cell. (3) Molecular layer.—This is formed of a matrix of neuroglia, imbedded in which are the *mitral cells*. These cells are pyramidal in shape, and the basal part of each gives off a thick dendrite which descends into one of the glomeruli, where it ends as indicated above, and others which interlace with similar dendrites of neighbouring mitral cells. The axons of the mitral cells pass into the next layer, and, bending backwards, are continued into the olfactory tract. (4) Nerve-fibre layer.—This lies next the central core of neuroglia, and its fibres consist of the axons of the mitral cells passing to the brain; some efferent fibres are, however, also present, and end in the molecular layer, but nothing is known as to their exact origin.

Weight of the brain.—The average weight of the brain, in the adult male, is about 1380 gms.; that of the female, about 1250 gms. In the male, the maximum weight out of 278 cases was 1840 gms. and the minimum weight 964 gms. The maximum weight of the adult female brain, out of 191 cases, was 1585 gms. and the minimum weight 879 gms. The brain increases rapidly during the first four years of life, and reaches its maximum weight by about the twentieth year. As age advances, the brain decreases slowly in weight; in old age the decrease takes place more rapidly, and may amount to about 28 gms.

The human brain is heavier than that of any of the lower animals, except the elephant and whale. The brain of the elephant weighs from 3500 to 4500 gms., and that of a whale, in a specimen 22·8 metres long, weighed rather more than 2250 gms.

Applied Anatomy.—The *internal capsule* is of great interest to the clinician because it is so often the seat of hæmorrhage from the lenticulo-striate and lenticulo-optic arteries (Charcot's 'arteries of cerebral hæmorrhage'), or of thrombosis, in patients whose vessels are weakened by old age or disease. A 'stroke,' or 'apoplexy,' is the result; blood is effused from the ruptured vessel and tears up the surrounding brain tissue, and also interferes with the neighbouring fibres by the compression set up by its mass. If the hæmorrhage is sudden and at all large, rapid and complete loss of consciousness follows, with paralysis of the opposite side of the body and loss of control over the sphincters. If it is the occipital part of the internal capsule that is involved, the paralysis will be more marked in the leg than in the arm, and will be associated with hemianæsthesia, and also with homonymous hemianopsia or blindness of the corresponding halves of the two retinæ, the patient being unable to see objects on the opposite side of the body. If the hæmorrhage is very extensive blood often makes its way into the ventricles, and death may follow in a few hours or days without recovery of consciousness, and with hyperpyrexia. If the hæmorrhage is small, consciousness is soon regained, and a fair degree of recovery from the paralysis follows, particularly in the leg. If the hæmorrhage takes place very slowly, the hemiplegia sets in gradually (ingravescent apoplexy), with headache and gradual clouding of the faculties. It is the upper motor neuron (see p. 836) that is injured in cerebral hæmorrhage; hence the muscles on the affected side of the body become spastic, with increased reflexes, while such muscular atrophy as follows is mainly due to disuse. The cerebral arteries are liable to sudden obstruction by embolism in persons with heart disease, and by thrombosis in those with diseased arteries. The effects of either embolism or thrombosis here are comparable with those of cerebral hæmorrhage, though the resulting hemiplegia or paralysis is often more gradual in its onset, and less severe in its general results.

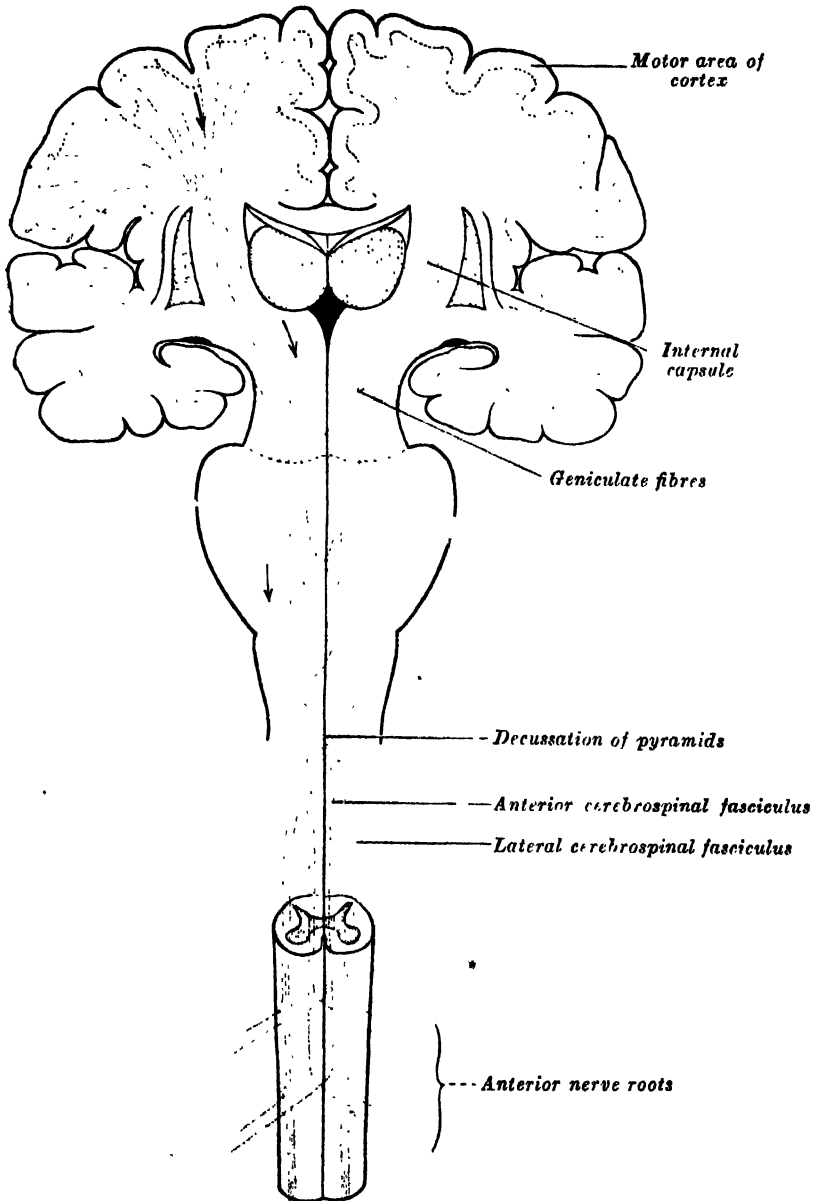
MOTOR AND SENSORY TRACTS

The anatomy of the various parts of the central nervous system having been described, a short account will now be given of the chief motor and sensory nerve-tracts connecting the brain and the medulla spinalis. The methods employed in elucidating this complex subject have already been referred to (p. 754).

MOTOR TRACT (fig. 797)

The constituent fibres of this tract are the axis-cylinder processes of cells situated in the motor area of the cortex. The fibres converge as they descend through the corona radiata, and pass between the lentiform nucleus and

FIG. 797.—The motor tract. (Modified from Poirier.)



thalamus, in the genu and anterior two-thirds of the occipital part of the internal capsule; those in the genu are named the geniculate fibres, while the remainder constitute the cerebrospinal fibres; proceeding downwards, they enter the middle three-fifths of the base of the cerebral peduncle. The geniculate fibres cross the middle line, and end by arborising around the cells of the motor nuclei of the cerebral nerves. The cerebrospinal fibres are continued

downwards into the pyramids of the medulla oblongata, and the transit of the fibres from the medulla oblongata is effected by two paths. The fibres nearest to the anterior median fissure cross the middle line, forming the *decussation of the pyramids*, and descend in the opposite lateral funiculus of the medulla spinalis, as the lateral cerebrospinal fasciculus (crossed pyramidal tract). Throughout the length of the medulla spinalis fibres from this column pass into the grey substance, to terminate by ramifying around cells of the posterior column, the axons of which in turn make contact with the motor cells of the anterior column. The more laterally placed cerebrospinal fibres do not decussate in the medulla oblongata, but descend as the anterior cerebrospinal fasciculus (direct pyramidal tract); these fibres, however, end in the grey column of the opposite side of the medulla spinalis after crossing in the anterior white commissure. There is considerable variation in the extent to which decussation takes place in the medulla oblongata; about two-thirds or three-fourths of the fibres usually decussate in the medulla oblongata and the remainder in the medulla spinalis.

The axons of the motor cells in the anterior column pass out as the fibres of the anterior roots of the spinal nerves, along which the impulses are conducted to the muscles of the trunk and limbs.

From this it will be seen that, generally speaking, the fibres of the motor tract pass to the nuclei of the motor nerves on the opposite side of the brain or medulla spinalis, a fact which explains why a lesion involving the motor area of one side causes paralysis of the muscles of the opposite side of the body. As already stated (p. 755) there is experimental and clinical evidence to show that a few of the cerebrospinal fibres do not decussate (uncrossed fibres). There is a break in the continuity of the motor chain: in the case of the cerebral nerves this break occurs in the nuclei of these nerves; and in the case of the spinal nerves, in the anterior grey column of the medulla spinalis. For clinical purposes it is convenient to emphasise this break and divide the motor tract into two portions: (1) a series of *upper motor neurons* which comprises the motor cells in the cortex and their descending fibres down to the nuclei of the motor nerves; (2) a series of *lower motor neurons* which includes the cells of the nuclei of the motor cerebral nerves and the cells of the anterior columns of the medulla spinalis and their axis-cylinder processes to the periphery.*

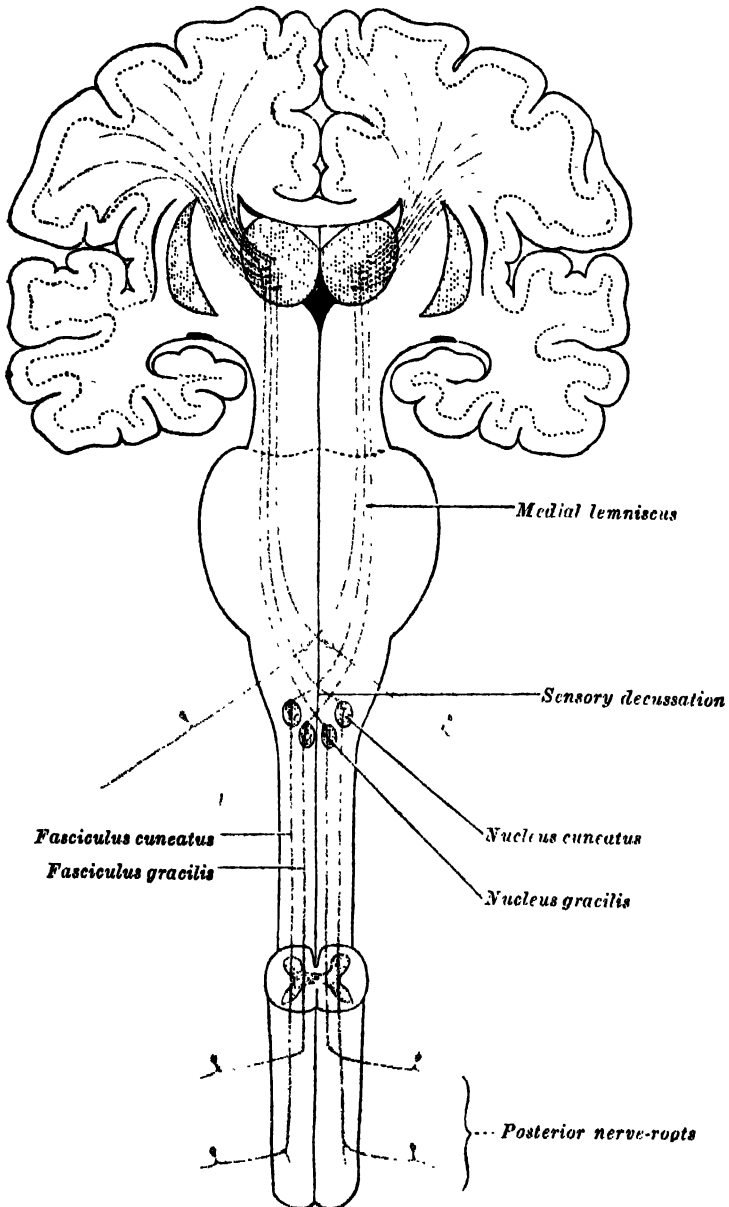
SENSORY TRACT (fig. 798).

Sensory impulses are conveyed to the medulla spinalis through the posterior roots of the spinal nerves. On entering the medulla spinalis these root-fibres divide into descending and ascending branches; the descending branches soon enter and ramify in the grey substance: some of the ascending branches also enter and ramify in the grey substance, but others are continued directly into the posterior funiculi, where they form the fasciculus gracilis and fasciculus cuneatus. Fibres arise from the cells of the dorsal nucleus (Clarke's column), cross the middle line, and ascend in the superficial anterolateral fasciculus. The fibres of the fasciculus gracilis and fasciculus cuneatus end by arborising around the cells of the nucleus gracilis and nucleus cuneatus in the medulla oblongata, and from these cells the fibres of the medial lemniscus take origin and cross to the opposite side in the *sensory decussation*. The medial lemniscus is then joined by the superficial anterolateral fasciculus, the fibres of which have already crossed in the medulla spinalis, and in its further course, the medial lemniscus receives fibres from the terminal nuclei of the cerebral sensory nerves of the opposite side, with the exception of the terminal nuclei of the cochlear nerve. Ascending through the cerebral peduncle, the medial lemniscus gives off a few fibres to the lentiform nucleus and insula, but the greater part of it is carried into the thalamus, where its fibres end. From the cells of the thalamus the fibres of the third link in the chain arise and pass to the cerebral cortex. The fibres from the terminal nuclei of the cochlear nerve pass upwards

* As already mentioned (footnote, p. 755), a neuron in the posterior column of the medulla spinalis is probably interposed between each upper and lower motor neuron.

in the lateral lemniscus, and are carried through the occipital part of the internal capsule to the temporal lobe. Further, the superficial anterolateral fasciculus gives off fibres which reach the cerebellum through the brachium conjunctivum. It will be evident, therefore, that in most cases there are three cell-stations

FIG. 798.—The sensory tract. (Modified from Poirier.)



interposed in the course of the sensory impulses. For clinical purposes, therefore, three neurons are described: (1) the *lowest sensory neurons* which comprise the cells of the posterior root ganglia and their peripheral and central processes; (2) the *intermediate sensory neurons* which are the cells of the nucleus gracilis and nucleus cuneatus and their processes; (3) the *highest sensory neurons* which are the cells of the thalami and the fibres passing from these to the cerebral cortex.

Applied Anatomy.—The chief symptoms of diseases of the brain and medulla spinalis depend upon the particular systems of neurons picked out for attack, and some of them may be briefly summarised as follows. *Motor paralysis* of the *spastic* type, with rigidity of the muscles and increased reflexes, follows destruction of the upper motor neurons; *flaccid* paralysis, with loss of the reflexes and rapid muscular atrophy, follows destruction of the lower motor neurons. *Sensory paralysis* follows injury to any part of the sensory path; in tabes it is due to injury of the lowest sensory neurons, in hemiplegia to destruction of the highest sensory axon as it traverses the occipital part of the internal capsule. *Dissociation of sensations*, or the loss of some forms of sensation while others remain unimpaired, is seen in a number of conditions such as tabes or syringomyelia; it shows that the paths through which various forms of sensation travel to the brain are different. *Abnormalities of reflex actions* are of very great help in the diagnosis of nervous complaints. The numerous *superficial or skin reflexes* (e.g. the scapular, irritation of the skin over the scapula produces contraction of the scapular muscles; the abdominal, stroking the abdomen causes its retraction; the cremasteric, stroking the inner side of the thigh causes retraction of the testis on that side; the plantar, tickling the sole of the foot brings on plantar flexion of the toes), if present, show that the reflex arcs on whose integrity their existence depends are intact; but they often are absent in health and so cannot be trusted to indicate disease. The *deep reflexes* or *tendon reactions*, such as the knee-jerk, or the tendo calcaneus jerk, are increased in chronic degeneration of, or gradually increasing pressure on, the cerebrospinal fibres (upper motor neuron), in nervous or hysterical patients, and when the irritability of the cells of the anterior column (lower motor neuron) is increased, as happens in tetanus or in poisoning by strychnine. They are lost when the lower motor or lower sensory neurons are diseased, and in a few other conditions; absence of the knee-jerk is very rare in health, and suggests disease in some part of its reflex arc, in the third and fourth lumbar segments of the cord, or else, more rarely, grave intracranial or spinal disease cutting off the lower from the higher nervous centres. The *organic reflexes* of the pupil, bladder, and rectum are of the greatest practical importance. The commonest defect in the reflexes of the pupil is reflex iridoplegia, or failure to contract on exposure to light, without failure to contract on convergence or accommodation ('Argyll Robertson' pupil). The pupil is also contracted (miosis), and may or may not dilate when the skin of the neck is pinched (the ciliospinal reflex). Micturition is a spinal reflex much under the control of the brain; if the centre for micturition in the second sacral segment is destroyed the sphincter and the walls of the bladder are paralysed, the bladder becomes distended with urine, and incontinence from overflow results. If this centre escapes injury but is cut off more or less completely from impulses descending to it from above, there will be more or less interference with micturition. This varies in degree from the 'precipitate micturition' of tubercular patients, who must perforce hurry to pass water the moment the impulse seizes them, to the state of 'reflex incontinence,' when the bladder automatically empties itself from time to time, almost without the patient's knowledge. Defecation is a very similar spinal reflex, and is liable to very similar disorders of function.

The *upper motor neuron* (p. 836) is affected in hemiplegia, the *lower motor neuron* (p. 836) in infantile spinal paralysis; both these systems of neurons are diseased together in the somewhat rare disorders known as amyotrophic lateral sclerosis and progressive muscular atrophy. The chief symptom here is wasting and weakness in certain groups of muscles; the palsy will be flaccid, with loss of the reflexes, or spastic, with increased reflexes, according as the degeneration mainly involves the lower or the upper motor neuron. The sphincters are affected only in the later stages of these diseases.

Pathological changes in the *lowest sensory neuron* are the cause of tabes dorsalis or locomotor ataxy, which occurs almost entirely in adults who have had syphilis. In the early or pre-ataxic stage the patient may exhibit the Argyll Robertson pupil (see above), and loss of knee-jerks, and complain of sharp, stabbing pains ('lightning pains') in the limbs, difficult or precipitate micturition, and sometimes of severe and painful attacks of indigestion (gastric crises). In the second or ataxic stage, coming on perhaps years later, he will complain, in addition, of interference with his powers of getting about and turning, although his muscular strength is well preserved. He is unable to stand steady with his eyes shut or in the dark, his gait becomes exaggerated and stamping in character, he has to use a stout stick to walk with, and he may suffer from painful crises in various parts of the body. Control over the sphincters is further weakened, and on examination there will be found marked incoordination of the limbs, zones of anaesthesia about the trunk or down the limbs, and marked analgesia (or insensitiveness to pain) when pressure is applied to the bones, tendons, trachea, tongue, eyeballs, mammae, and testes. The ataxy progresses till the third or bedridden stage is reached; control over the sphincters is still further lost, and the patient is likely to die of intercurrent disease or of general paralysis of the insane.

No nervous disease is recognised as dependent upon degeneration of either the *intermediate* or *highest sensory neuron*.

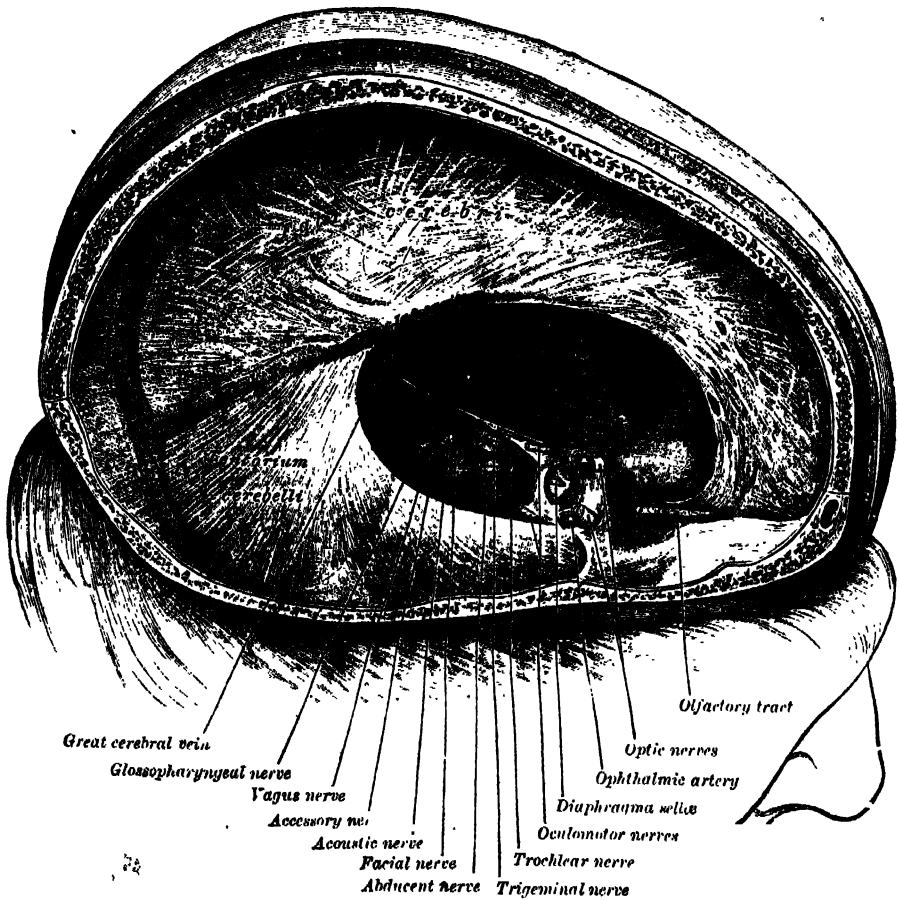
MENINGES OF THE BRAIN AND MEDULLA SPINALIS

The brain and the medulla spinalis are enveloped by three membranes, named from without inwards: the dura mater, the arachnoid, and the pia mater.

R. THE DURA MATER

The dura mater is a thick and dense inelastic membrane. The portion of it which encloses the brain (cerebral dura mater) differs in several particulars from that which surrounds the medulla spinalis (spinal dura mater), and

FIG. 799.—The dura mater and its processes exposed by removing a part of the right half of the skull, and the brain.

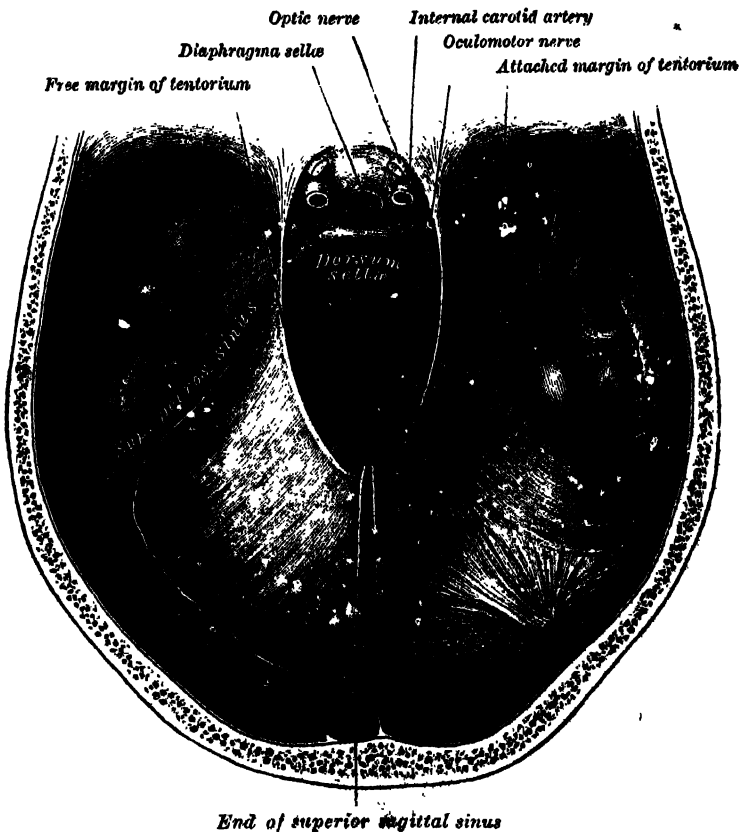


therefore it is necessary to describe them separately; the two parts, however, form one complete membrane, and are continuous with one another at the foramen magnum.

The cerebral dura mater lines the interior of the skull, and serves the two-fold purpose of an internal periosteum to the bones, and a protective membrane for the brain. It is composed of two layers, an inner or meningeal and an outer or endosteal; these are closely united, except along certain lines where they are separated by the blood sinuses which drain the blood from the brain (p. 680). The dura mater adheres to the inner surfaces of the cranial

bones, and sends blood-vessels and fibrous processes into them. These blood-vessels and fibrous processes are torn across when the dura mater is detached, and the outer surface of the latter presents a rough and fibrillated appearance. The inner surface, on the other hand, is smooth and lined by a layer of endothelium. The adhesion of the dura mater is most marked at the sutures, at the base of the skull and around the foramen magnum. It is continuous through the sutures with the pericranium, and through the superior orbital fissure with the periosteal lining of the orbital cavity. It sends tubular sheaths on the cerebral nerves as the latter pass through the foramina at the base of the skull; outside the skull these sheaths fuse with the epineurium of the nerves; the sheath surrounding the optic nerve blends anteriorly with the sclera of the bulb of the eye.

FIG. 800.—The tentorium cerebelli. Seen from above.



The dura mater sends inwards four processes which divide the cavity of the skull into a series of freely communicating spaces for the lodgment and protection of the brain. These processes consist of reduplications of the inner or meningeal layer of the membrane and are named the *falx cerebri*, the *tentorium cerebelli*, the *falx cerebelli*, and the *diaphragma sellæ*.

The *falx cerebri* (fig. 799), so named from its sickle-like form, is a strong, arched process of dura mater which descends vertically in the longitudinal fissure between the cerebral hemispheres. It is narrow in front, where it is fixed to the crista galli of the ethmoidal bone; and broad behind, where it is attached to the middle line of the upper surface of the *tentorium cerebelli*; the narrow, anterior part is thin, and is frequently perforated by numerous apertures. Its upper margin is convex, and attached to the inner surface of the skull on either side of the middle line, as far back as the internal occipital protuberance; the superior sagittal sinus runs along this margin. Its lower

margin is free and concave, and contains the inferior sagittal sinus. The straight sinus runs along its attachment to the tentorium cerebelli.

The *tentorium cerebelli* (fig. 800) is an arched lamina of dura mater which covers the superior surface of the cerebellum, and supports the occipital lobes of the brain. Its concave, anterior border is free, and bounds a large oval opening, the *incisura tentorii*, which is occupied by the mesencephalon. Its convex, posterior border is attached behind to the lips of the transverse sulci on the inner surface of the occipital bone, and there encloses the transverse sinuses; in front, to the superior angle of the petrous part of the temporal bone on either side, enclosing the superior petrosal sinuses. At the apex of the petrous part of the temporal bone the free and attached borders cross one another, and are continued forwards to be fixed to the anterior and posterior clinoid processes respectively. As already stated, the posterior border of the falx cerebri is attached to the median line of the upper surface of the tentorium cerebelli, and the straight sinus lies in this line of attachment.

The *falx cerebelli* is a small, medially placed triangular process of dura mater which is situated below the tentorium cerebelli, and projects forwards into the posterior cerebellar notch. Its base, directed upwards, is attached to the posterior part of the tentorium; its posterior margin contains the occipital sinus, and is attached to the internal occipital crest; its apex frequently divides into two small folds, which are lost on the sides of the foramen magnum.

The *diaphragma sellæ* is a small circular horizontal fold of dura mater, which roofs the sella turcica and almost completely covers the hypophysis; a small opening in its centre transmits the infundibulum.

Structure.—The cranial dura mater consists of white fibrous tissue and elastic fibres arranged in flattened laminae which are imperfectly separated by lacunar spaces and blood-vessels into the endosteal and meningeal layers, already referred to. The endosteal layer is the internal periosteum for the cranial bones, and contains the blood-vessels for their supply. At the margin of the foramen magnum it is continuous with the periosteum lining the vertebral canal. The meningeal layer is lined on its inner surface by a layer of nucleated endothelium.

The arteries of the dura mater are very numerous. Those in the anterior fossa are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid arteries; and a branch from the middle meningeal artery. Those in the middle fossa are the middle and accessory meningeal branches of the internal maxillary artery; a branch from the ascending pharyngeal artery, which enters the skull through the foramen lacerum; branches from the internal carotid artery, and a recurrent branch from the lacrimal artery. Those in the posterior fossa are meningeal branches from the occipital artery, one entering the skull through the jugular foramen, and another through the mastoid foramen; the posterior meningeal from the vertebral artery; occasional meningeal branches from the ascending pharyngeal artery, entering the skull through the jugular foramen and hypoglossal canal; and a branch from the middle meningeal artery.

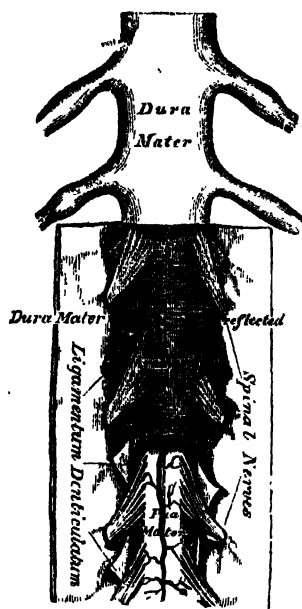
The veins returning the blood from the cranial dura mater anastomose with the diploic veins and end in the cranial blood-sinuses. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of ampullæ, termed *venous lacunæ*. These lacunæ are found on either side of the superior sagittal sinus, especially near its middle portion, and are often invaginated by arachnoidal granulations; they also exist near the transverse and straight sinuses. They communicate with the underlying cerebral veins, and also with the diploic and emissary veins.

The nerves of the cerebral dura mater are filaments from the semilunar ganglion of the trigeminal nerve, from the ophthalmic, maxillary, mandibular, vagus, and hypoglossal nerves, and from the sympathetic.

The spinal dura mater (figs. 801, 804) forms a loose sheath around the medulla spinalis, and represents only the inner or meningeal layer of the cerebral dura mater; the outer or endosteal layer ceases at the foramen magnum, its place being taken by the periosteum lining the vertebral canal. The spinal dura mater is separated from the wall of the vertebral canal by a space, the *epidural space*, which contains a quantity of loose areolar tissue and a plexus of veins; the situation of these veins between the dura mater and the periosteum of the vertebrae corresponds therefore to that of the cranial sinuses between the meningeal and endosteal layers of the cerebral dura mater. The spinal dura mater is attached to the circumference of the foramen magnum, and to the second and third cervical vertebrae; it is also connected by fibrous

slips to the posterior longitudinal ligament of the vertebræ, especially near the lower end of the vertebral canal. The subdural cavity ends at the lower

FIG. 801.—The medulla spinalis and its membranes.



border of the second sacral vertebra; below this level the dura mater closely invests the filum terminale and descends to the back of the coccyx, where it blends with the periosteum. The dura mater is continued in the form of tubular prolongations on the roots of the spinal nerves and on to the complete spinal nerves as they pass through the intervertebral foramina. These prolongations are short in the upper part of the vertebral column, but gradually become longer below.

Structure.—The spinal dura mater resembles in structure the meningeal layer of the cranial dura mater; it consists of white fibrous and elastic tissue arranged in bands or lamellæ which, for the most part, are parallel with one another and have a longitudinal arrangement. Its internal surface is smooth and covered by a layer of endothelium. It is sparingly supplied with blood-vessels and nerves.

THE ARACHNOID

The arachnoid is a delicate membrane enveloping the brain and medulla spinalis and lying between the pia mater internally and the dura mater externally. It is separated from the dura mater by the *subdural space*, but here and

there this space is traversed by isolated connective tissue trabeculæ, which are most numerous on the posterior surface of the medulla spinalis. It is separated from the pia mater by the *subarachnoid cavity* which is filled with cerebrospinal fluid.

The arachnoid surrounds the cerebral and spinal nerves, and encloses them in loose sheaths as far as their points of exit from the skull and vertebral canal.

The *cerebral part of the arachnoid* invests the brain loosely, and does not dip into the sulci between the gyri, nor into the fissures, with the exception of the longitudinal. On the upper surface of the brain it is thin and transparent; at the base it is thicker, and slightly opaque towards the central part, where it extends between the two temporal lobes in front of the pons, so as to leave a considerable interval between it and the pia mater.

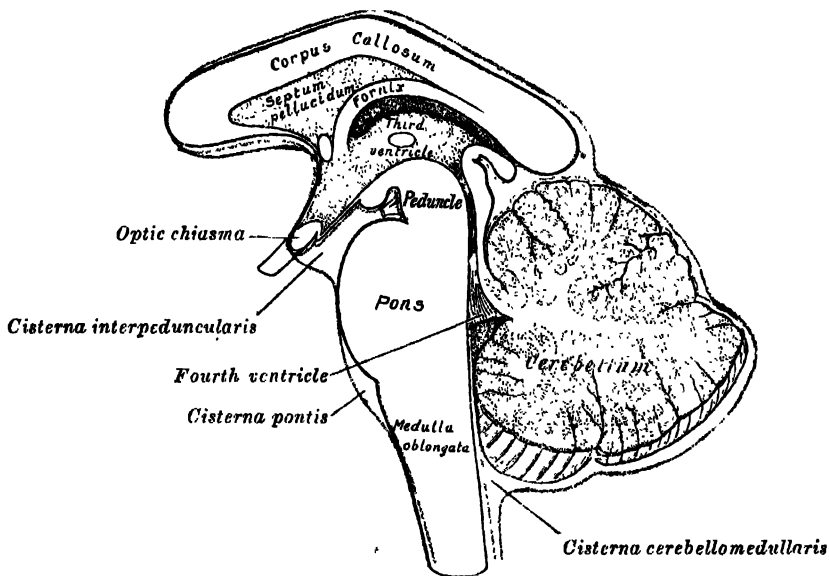
The *spinal part of the arachnoid* (figs. 801, 804) is a thin, delicate, tubular membrane loosely investing the medulla spinalis. Above, it is continuous with the cerebral arachnoid; below, it widens out and invests the cauda equina and the nerves proceeding from it.

Structure.—The arachnoid consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a layer of endothelium. Vessels of considerable size, but few in number, and, according to Boeckdalek, a rich plexus of nerves derived from the motor root of the trigeminal, the facial, and the accessory nerves, are found in the cerebral part of the arachnoid.

The *subarachnoid cavity* is the interval between the arachnoid and pia mater. It contains the cerebrospinal fluid and the larger blood-vessels of the brain, and is traversed by a spongy tissue, consisting of delicate trabeculæ of connective tissue, which connect the arachnoid to the pia mater. This cavity is small on the surface of the hemispheres of the brain; on the summits of the gyri the pia mater and the arachnoid are in close contact; but where the arachnoid bridges the sulci triangular spaces are left, in which the subarachnoid trabecular tissue is found. At certain parts of the base of the brain, the arachnoid is separated from the pia mater by wide intervals, which communicate freely with each other and are named *subarachnoid cisternæ*; in these the subarachnoid tissue is less abundant.

Subarachnoid cisternæ (fig. 802).—The *cisterna cerebellomedullaris* (*cisterna magna*) is triangular on sagittal section, and is formed by the arachnoid bridging the wide interval between the medulla oblongata and the under surfaces of the hemispheres of the cerebellum; it is continuous with the subarachnoid cavity of the medulla spinalis at the level of the foramen magnum. The *cisterna pontis* is a considerable space on the ventral aspect of the pons. It contains the basilar artery, and is continuous behind with the subarachnoid cavity of the medulla spinalis, and with the *cisterna cerebellomedullaris*, and in front of the pons with the *cisterna interpeduncularis*. The *cisterna interpeduncularis* (*cisterna basalis*) is a wide cavity where the arachnoid extends across between the two temporal lobes. It encloses the cerebral peduncles and the structures in the interpeduncular fossa, and contains the arterial circle of Willis. Anteriorly, the *cisterna interpeduncularis* is continuous with the *cisterna chiasmatis* which lies in front of the optic chiasma and is prolonged on to

FIG. 802.—A diagram showing the positions of the three principal subarachnoid cisternæ.



the upper surface of the corpus callosum; here the arachnoid stretches from one cerebral hemisphere to the other immediately beneath the free border of the falx cerebri, and thus leaves a space in which the anterior cerebral arteries are contained. The *cisterna fossæ cerebri lateralis* contains the middle cerebral artery, and is formed in front of either temporal lobe by the arachnoid bridging the lateral cerebral fissure. The *cisterna venæ magnæ cerebri* occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum; it extends between the layers of the tela chorioidea of the third ventricle and contains the great cerebral vein.

The subarachnoid cavity communicates with the general ventricular cavity of the brain by three openings: one, the *foramen of Majendie*, is in the middle line at the inferior part of the roof of the fourth ventricle; the other two are at the extremities of the lateral recesses of that ventricle, behind the upper roots of the glossopharyngeal nerves. It is stated by Meckel that the lateral ventricles also communicate with the subarachnoid cavity at the apices of their inferior cornua. There is no direct communication between the subdural and subarachnoid cavities.

The spinal part of the subarachnoid cavity is a wide interval, and is largest at the lower part of the vertebral canal, where the arachnoid encloses the nerves which form the cauda equina. Above, it is continuous with the cranial subarachnoid cavity; below, it ends at the level of the lower border of the second sacral vertebra. It is partially divided by a longitudinal septum,

the *subarachnoid septum*, which connects the arachnoid with the pia mater opposite the posterior median sulcus of the medulla spinalis, and forms a partition, incomplete and cribriform above, but more complete in the thoracic region. The spinal subarachnoid cavity is further subdivided by the *ligamentum denticulatum*, which will be described with the pia mater.

The cerebrospinal fluid is a clear, slightly alkaline fluid, with a specific gravity of about 1007. It contains in solution inorganic salts similar to those in the blood-plasma, and also traces of protein and glucose. It supports and protects the delicate structures of the brain and medulla spinalis, maintains a uniform pressure on them, and probably acts as their nutritive fluid.

It is produced by the action of the secreting cells which cover the chorioid plexuses of the brain, and is normally present at a certain pressure which is not dependent on the arterial or venous blood-pressure. Its secretion may be increased (a) by an excess of carbonic acid, (b) by volatile anæsthetics, or (c) by an extract of the chorioid plexuses or of the brain. Dyes added to the fluid travel along the courses of certain cerebral nerves (especially the olfactory nerves) but not along the spinal nerves.

When readily diffusible substances are introduced into the subcerebellar part of the subarachnoid cavity they produce typical physiological actions almost as rapidly as when injected into the venous circulation. The diffusion of such substances is, on the contrary, extremely slow in the lower spinal region.*

Applied Anatomy.—In various diseases, such as syphilis, meningitis, and infantile paralysis, changes take place in the chemical nature of the substances dissolved in the cerebrospinal fluid, or in the various cells found suspended in it; and these alterations are often of service in diagnosis.

Evidence of great value in the diagnosis of meningitis may sometimes be obtained by puncturing the spinal membranes and withdrawing some of the cerebrospinal fluid; moreover, the operation of lumbar puncture is in many cases curative, under the supposition that the draining of some of the cerebrospinal fluid relieves the patient by diminishing the intracranial pressure. The operation is performed by inserting a trocar, of the smallest size, between the laminae of the third and fourth, or of the fourth and fifth lumbar vertebrae, through the ligamentum flavum. The medulla spinalis, even of a child at birth, does not reach below the third lumbar vertebra, and therefore the canal may be punctured between the third and fourth lumbar vertebrae without any risk of injuring this structure. The point of puncture is indicated by laying the patient on the side and dropping a perpendicular line from the highest point of the iliac crest; this will cross the upper border of the spinous process of the fourth lumbar vertebra, and will indicate the level at which the trocar should be inserted a little to one side of the middle line. The puncture may require to be repeated more than once, and the greatest precaution must be taken not to allow septic infection of the meninges. If there be any appreciable increase of pressure, the fluid will flow through the trocar with the greatest freedom.

In addition to the constitutional signs and symptoms of fever, *acute spinal meningitis* exhibits certain characteristic features. Pain and tenderness to pressure along the vertebral column are common, and so are pains in the limbs or round the trunk from irritation of the posterior nerve-roots by the inflammatory products. Irritation of the anterior nerve-roots is shown by the increased tone of the muscles, which may go on to the point where they pass into a state of spasm with much-increased reflexes; this is often seen in the retraction of the head and neck. Later in the disease the reflexes are often lost, when, also, the urine and feces may be passed involuntarily.

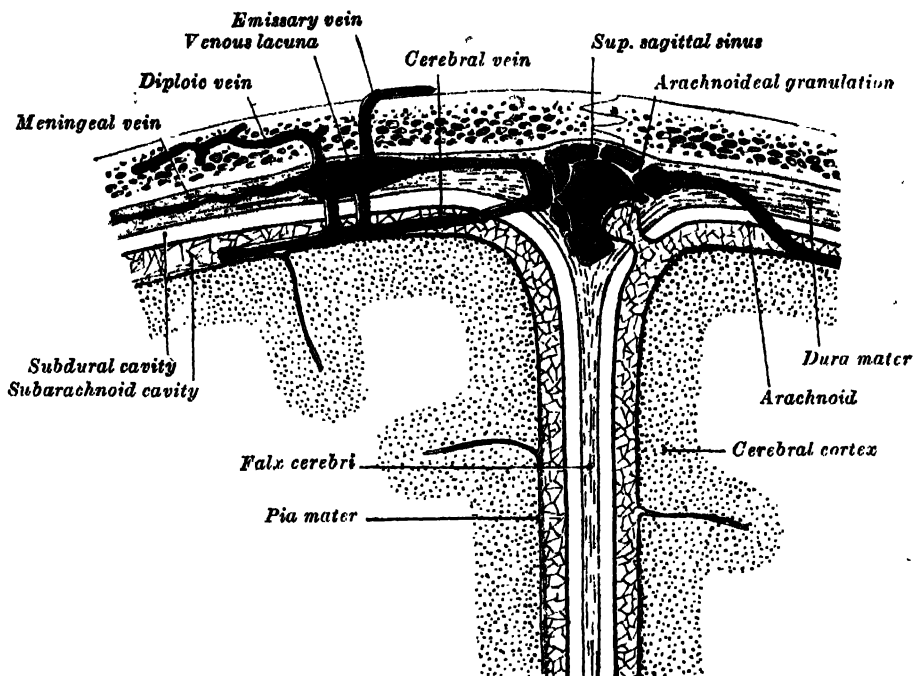
Spinal anæsthesia can be induced by injecting certain substances, especially stovaine, into the cerebrospinal fluid. It is done by means of a syringe attached to a lumbar puncture needle, and is especially valuable, when from any cause the administration of a general anæsthetic is inadvisable; but any operation below the level of the umbilicus (10th thoracic nerve) can be performed painlessly by this method.

The arachnoideal granulations (*glandulae Pacchionii*) (fig. 803) are small fleshy-looking elevations, usually collected into clusters of variable size, which are present upon the outer surface of the dura mater, in the vicinity of the superior sagittal sinus, and in some other situations. Upon laying open the sagittal sinus and the venous lacunae on either side of it, granulations will be found protruding into their interior. They are very rarely developed until the third year; they are usually found after the seventh year; and from this period they increase in number and size as age advances. They are enlarged normal villi of the arachnoid, which as they grow push the thinned dura mater before them, and cause absorption of the bone from pressure, and so produce the pits or depressions on the inner wall of the calvarium.

*Consult articles by Dixon and Halliburton, *Journal of Physiology*, vol. x., and Halliburton, *British Medical Journal*, Nov. 4, 1918.

Structure.—An arachnoideal granulation consists of the following parts : 1. In the interior is a core of subarachnoid tissue, continuous with the meshwork of the general subarachnoid tissue through a narrow pedicle, by which the granulation is attached to the arachnoid. 2. Around this tissue is the arachnoid membrane. 3. Outside this is the thinned wall of the lacuna, which is separated from the arachnoid by the subdural cavity. 4. If the granulation projects into the sagittal sinus, it

Fig. 803.—A diagrammatic representation of a section across the top of the skull, showing the membranes of the brain, &c. (Modified from Testut.)



is covered by the greatly thinned wall of the sinus. Fluid injected into the sub-arachnoid cavity will find its way into these granulations, and it has been found experimentally that fluid passes by osmosis from the granulations into the venous sinuses into which they project.

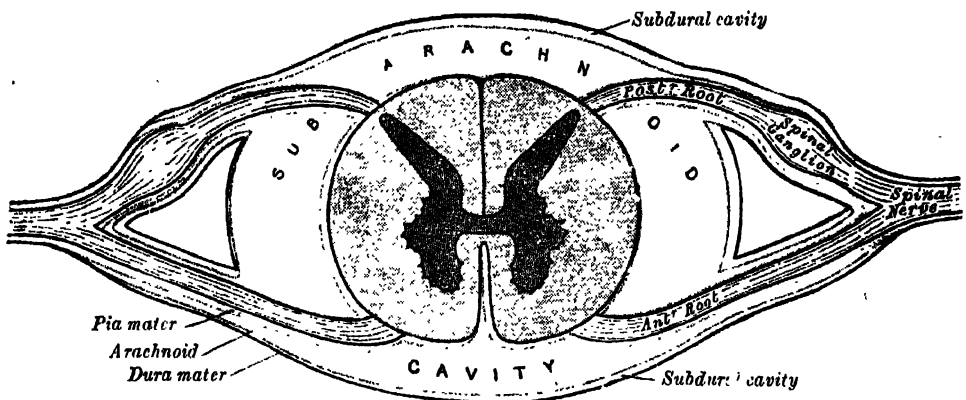
THE PLA MATER

The **pia mater** closely invests the brain and medulla spinalis; it is a vascular membrane, consisting of a minute plexus of blood-vessels, held together by an extremely fine areolar tissue. The *cerebral pia mater* invests the entire surface of the brain, dips between the cerebral gyri and cerebellar laminæ, and is invaginated to form the tela chorioidea of the third ventricle, and the chorioid plexuses of the lateral and third ventricles (pp. 826, 827); as it passes over the roof of the fourth ventricle, it forms the tela chorioidea and the chorioid plexuses of this ventricle (p. 785). Upon the surfaces of the hemispheres, where it covers the grey substance, it gives off from its deep surface a multitude of sheaths around the minute vessels that extend perpendicularly for some distance into the cerebral substance. On the cerebellum the membrane is more delicate; the vessels from its deep surface are shorter, and its relations to the cortex are not so intimate.

The *spinal pia mater* (figs. 801, 804) is thicker, firmer, and less vascular than the cerebral pia mater; this is due to the fact that it consists of two layers, the outer or additional one being composed of bundles of connective tissue fibres, arranged for the most part longitudinally. Between the layers are cleft-like spaces which communicate with the subarachnoid cavity, and a number of blood-vessels which are enclosed in perivascular lymphatic sheaths.

The spinal pia mater covers the entire surface of the medulla spinalis, and is intimately adherent to it; in front it sends a process backwards into the anterior fissure. A longitudinal fibrous band, called the *linea splendens*, extends along the middle line of the anterior surface, and a somewhat similar band, the *ligamentum denticulatum*, is situated on either side. Below the conus medullaris the pia mater is continued as a long slender filament (*filum terminale*), which descends through the centre of the mass of nerves forming the cauda equina. The *filum terminale* blends with the dura mater at the level of the lower border of the second sacral vertebra, and extends downwards as far as the base of the coccyx, where it fuses with the periosteum; it assists in maintaining the medulla spinalis in position during the movements of the trunk, and is, from this circumstance, called the *central ligament* of the medulla spinalis.

FIG. 804.—A diagrammatic transverse section of the medulla spinalis and its membranes.



The pia mater forms sheaths for the cerebral and spinal nerves; these sheaths are closely connected with the nerves, and blend with their common membranous investments.

The *ligamentum denticulatum* (fig. 801) is a narrow fibrous band situated on either side of the medulla spinalis throughout its entire length, and separating the anterior from the posterior nerve-roots. Its medial border is continuous with the pia mater at the side of the medulla spinalis. Its lateral border presents a series of triangular tooth-like processes, the points of which are fixed at intervals to the dura mater. These processes are twenty-one in number, on either side. The first process crosses behind the vertebral artery at the point where that vessel pierces the dura mater, and is separated by the artery from the first cervical nerve; it is attached to the dura mater immediately above the margin of the foramen magnum, 1.25 cm. behind the hypoglossal nerve. The last process is between the exits of the twelfth thoracic and first lumbar nerves, and consists of a narrow oblique band running downwards and lateralwards from the conus medullaris (Parsons *).

CEREBRAL NERVES

There are twelve pairs of cerebral nerves, which are named from before backwards as follows:

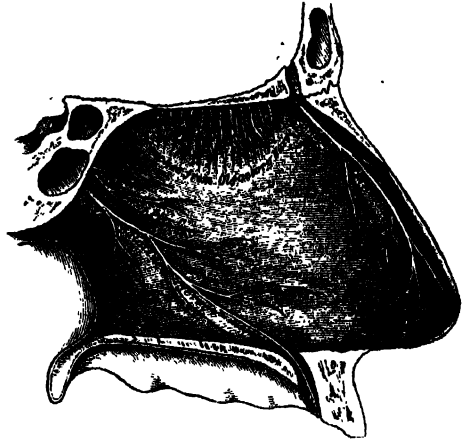
- | | | |
|----------------------------|------------------|------------------------|
| 1st. Olfactory. | 5th. Trigeminal. | 9th. Glossopharyngeal. |
| 2nd. Optic. | 6th. Abducent. | 10th. Vagus. |
| 3rd. Oculomotor. | 7th. Facial. | 11th. Accessory. |
| 4th. Trochlear (Pathetic). | 8th. Acoustic. | 12th. Hypoglossal. |

These nerves are attached to the brain, and are transmitted through openings in the base of the cranium. The fibres of the nerves can be traced into the

* *Proceedings of the Anatomical Society of Great Britain and Ireland, 1915.*

substance of the brain to special nuclei of grey substance. The motor or efferent cerebral nerves arise within the brain from groups of nerve-cells which constitute their *nuclei of origin*. The sensory or afferent cerebral nerves arise from nerve-cells outside the brain; these nerve-cells may be grouped to form ganglia on the trunks of the nerves, or may be situated in peripheral sensory organs such as the nose and eye. The centrally directed processes of the cells run into the brain, and there end by arborising around nerve-cells, which are grouped to form *nuclei of termination*. The nuclei of origin of the motor nerves and the nuclei of termination of the sensory nerves are brought into relationship with the cerebral cortex, the former through the geniculate fibres of the internal capsule, the latter through the lemniscus. The geniculate fibres of the internal capsule arise from the cells of the motor area of the cortex; they cross the middle line, and end by arborising around the cells of the nuclei of origin of the motor cerebral nerves. On the other hand, fibres arise from the cells of the nuclei of termination of the sensory nerves, and, after crossing to the opposite side, join the lemniscus, and thus connect the nuclei of termination, directly or indirectly, with the cerebral cortex.

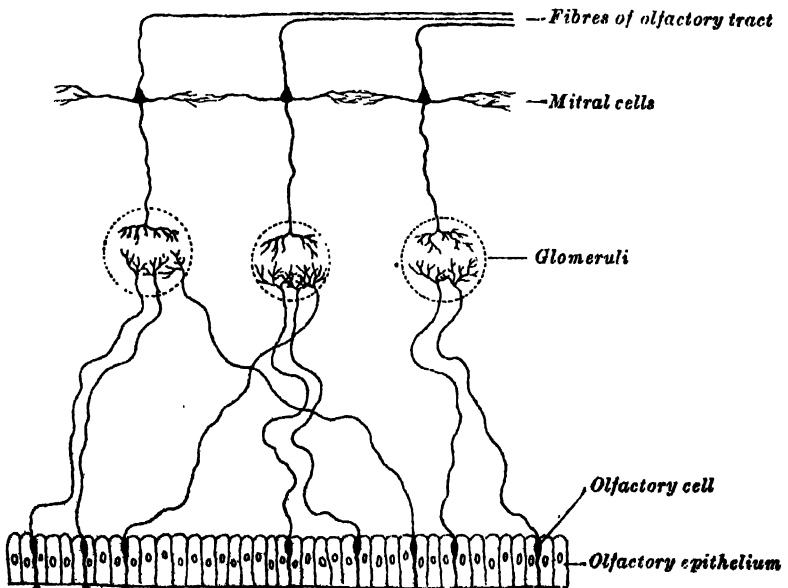
FIG. 805.—The nerves of the septum of the nose. Right side.



OLFACTORY NERVES (fig. 805)

The olfactory nerves, or nerves of smell, are distributed to the mucous membrane of the olfactory region of the nasal cavity; this region comprises

FIG. 806.—A plan of the olfactory neurons.



the superior nasal concha, and the opposed part of the nasal septum. The nerve-fibres originate from the central or deep processes of the olfactory cells

of the nasal mucous membrane, and are collected into bundles which cross one another in various directions, and thus give rise to the appearance of a plexiform network in the mucous membrane. They are then collected into about twenty branches, which pierce the lamina cribrosa of the ethmoidal bone in a lateral and a medial group, and end in the glomeruli of the olfactory bulb (fig. 806). Each branch receives tubular sheaths from the dura mater and pia mater, the former being continued into the periosteum of the nose, the latter into the neurolemma of the nerve.

The olfactory nerves are non-medullated, and consist of axis-cylinders surrounded by nucleated sheaths, in which, however, there are fewer nuclei than in the sheaths of ordinary non-medullated nerve-fibres.

The olfactory centre in the cortex is generally associated with the rhinencephalon (p. 812).

Applied Anatomy.—In severe injuries to the head involving the anterior fossa of the base of the skull, the olfactory bulb may become separated from the olfactory nerves or the nerves may be torn, thus producing loss of smell (*anosmia*), and with this there is a considerable loss in the sense of taste, since much of the perfection of the sense of taste is due to the substances being also odorous, and simultaneously exciting the sense of smell.

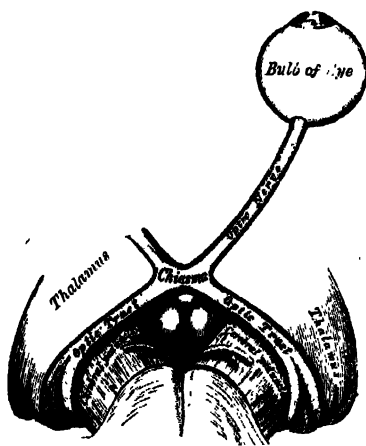
Anosmia often occurs after influenza or other acute infection of the nose. Parosmia, or a perversion of the sense of smell, may occur in lesions of the cortical olfactory centres, or in insanity.

OPTIC NERVE (fig. 807)

The optic nerve or nerve of sight is distributed exclusively to the bulb of the eye. Most of its fibres are afferent and originate in the nerve-cells of the ganglionic layer of the retina (p. 962), but a few are efferent and spring from nerve-cells in the lower visual centres of the brain (p. 797).

The fibres of the optic nerve form the innermost layer (stratum opticum) of the retina; they converge to the optic disc, and then pierce the chorioid

FIG. 807.—The left optic nerve, the optic chiasma, and the optic tracts.



coat and the lamina cribrosa at the posterior part of the bulb of the eye, about 3 or 4 mm. to the nasal side of its centre. As the nerve-fibres traverse the lamina cribrosa they receive their medullary sheaths and run in bundles which are collected to form the optic nerve.

The optic nerve is directed backwards and medialwards through the posterior part of the orbital cavity. It then runs through the optic foramen into the cranial cavity and joins the optic chiasma.

The part of the nerve contained in the orbital cavity is about 25 mm. long. It is surrounded by the rectus muscles, but is separated from them by a quantity of fat in which the ciliary vessels and nerves are lodged. The ciliary ganglion lies between the nerve and the Rectus lateralis muscle. The nerve is pierced below, at a distance of about 12 mm. behind the bulb of the eye, by the central artery and

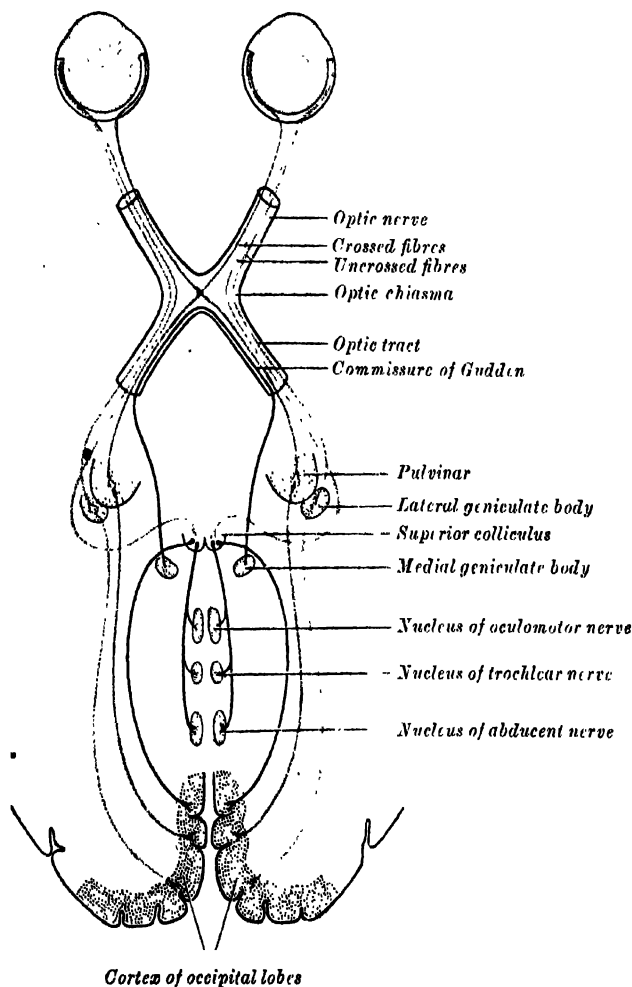
vein of the retina, which are then directed forwards in the centre of the nerve to the optic disc. Near the optic foramen the ophthalmic artery runs forwards and medialwards across the nerve. In the optic foramen this artery lies beneath and laterally to the nerve, which is here separated medially from the sphenoidal and posterior ethmoidal air-sinuses by a thin lamina of bone.

The intracranial part of the optic nerve, about 10 mm. long, runs backwards and medialwards from the optic foramen to the optic chiasma. Above it are the posterior parts of the olfactory tract and gyrus rectus, and, near the chiasma, the anterior cerebral artery. On its lateral side is the internal carotid artery.

The optic nerve consists mainly of fine medullated fibres, and is enclosed in three sheaths which are continuous with the membranes of the brain. It is in fact an outlying part of the white substance of the brain.

The *outer sheath*, derived from the dura mater, is thick and fibrous, and blends anteriorly with the sclera of the bulb of the eye. The *intermediate sheath*, derived from the arachnoid membrane, is thin and delicate. It is separated from the outer sheath by a narrow lymph-space which is continuous posteriorly with the subdural space, and from the inner sheath by a wider space which is continuous posteriorly with the subarachnoid cavity. The *inner sheath*, derived from the pia mater, is vascular and closely invests the nerve. From its deep surface septa pass into the nerve and subdivide and

FIG. 808.—A scheme showing the central connexions of the optic nerves and optic tracts.



reunite to enclose what appear, in transverse sections of the nerve, as polygonal areas which are occupied by the bundles of nerve-fibres. From the inner sheath also, an investment is carried on the central vessels of the retina as far as the optic disc.

The **optic chiasma** or **commissure**, somewhat quadrilateral in shape, lies above the tuberculum sellæ and the anterior part of the diaphragma sellæ, some distance behind the so-called sulcus chiasmatis of the sphenoidal bone. It forms the anterior part of the floor of the third ventricle and is in relation above with the lamina terminalis, behind with the tuber cinereum, and laterally with the anterior perforated substance and the internal carotid artery.

The fibres of the optic nerve undergo a partial decussation in the optic chiasma (fig. 808). The fibres from the medial (nasal) half of the retina cross

the middle line in the central part of the chiasma and enter the optic tract of the opposite side. The fibres from the lateral (temporal) half of the retina do not cross, but are continued backwards, through the lateral part of the chiasma, into the optic tract of the same side. The posterior part of the chiasma consists of fibres which cross the middle line, but do not form parts of the optic nerves; these fibres connect the medial geniculate bodies of opposite sides and constitute what is known as the *Commissure of Gudden*.

The optic tract is a cylindrical bundle of nerve-fibres which runs backwards and lateralwards from the optic chiasma. It passes between the anterior perforated substance and the tuber cinereum, and reaches the under surface of the cerebral peduncle, where it becomes flat, and is attached to the peduncle by its anterior margin. It then winds round the peduncle and divides into a medial and a lateral root. The fibres of the medial root form the commissure of Gudden, already referred to, and pass to the medial geniculate body. The lateral and larger root ends in the lateral geniculate body, the pulvinar of the thalamus and the superior colliculus, which together constitute the *lower visual centres*. From the cells of these centres fibres, termed the *optic radiations*, are prolonged through the occipital part of the internal capsule to the *higher or cortical visual centre*, which is situated in the cuneus and in the neighbourhood of the calcarine fissure.

Some fibres are detached from the optic tract, and pass through the cerebral peduncle to the nucleus of the oculomotor nerve. These fibres are small, and may be regarded as afferent branches for the Sphincter pupillæ and Ciliaris muscles. Other fibres pass to the cerebellum through the brachia conjunctiva, while others end in the nuclei of the pons.

Applied Anatomy.—The optic nerve is peculiarly liable to become the seat of neuritis or undergo atrophy in affections of the central nervous system, and as a rule the pathological relationship between the two affections is exceedingly difficult to trace. There are, however, certain points in connexion with the anatomy of this nerve which tend to throw light upon the frequent association of these affections with intracranial disease. (1) From its mode of development, and from its structure, the optic nerve must be regarded as a prolongation of the brain substance, rather than as an ordinary cerebral nerve. (2) It receives sheaths from the three cerebral membranes, and these sheaths are separated from each other by spaces which communicate with the subdural and subarachnoid cavities respectively. The innermost sheath sends a process around the arteria centralis retinae into the interior of the nerve, and enters intimately into its structure. Thus inflammatory affections of the meninges or of the brain may readily extend along these spaces, or along the interstitial connective tissue in the nerve.

The optic neuritis or papillitis ("choked disc") that is often seen in cases of intracranial new growth with increased intracranial tension is probably caused by increased pressure in the vaginal sheath of the optic nerve, due to excess of fluid in the general subarachnoid space with which this sheath is in direct communication. If, as is the case, for example in the internal hydrocephalus seen as a complication of cerebro-spinal fever, there is no increase in the amount of fluid in the subarachnoid space, then there will be no optic neuritis although the intracranial tension may rise until it brings about the patient's death.

The course of the fibres in the optic chiasma has an important pathological bearing and has been the subject of much controversy. Microscopic examination, experiments, and pathology all seem to point to the fact that there is a partial decussation of the fibres, each optic tract supplying the corresponding half of each eye, so that the right tract supplies the right half of each eye, and the left tract the left half of each eye. At the same time Charcot believes, and his view has met with general acceptance, that the fibres which do not decussate at the optic chiasma undergo decussation in the corpora quadrigemina, so that the lesion of the cerebral centre of one side causes complete blindness of the opposite eye, because both sets of decussating fibres are destroyed; whereas if one tract, say the right, be destroyed by disease, there will be blindness of the right half of both retinae.

An anteroposterior section through the chiasma would divide the decussating fibres, and would therefore produce blindness of the medial half of each eye; while a section at the margin of the side of the optic chiasma would produce blindness of the lateral half of the retina of the same side. An early symptom of tumour-growth in the hypophysis is pressure on the chiasma.

The optic nerve may also be affected in injuries or diseases involving the orbit; in fractures of the anterior fossa of the base of the skull; in tumours of the orbit itself, or those invading this cavity from neighbouring parts.

OCULOMOTOR NERVE (figs. 810, 811, 812)

The oculomotor nerve supplies all the ocular muscles, except the Obliquus superior and Rectus lateralis; it also supplies, through its connexion with the ciliary ganglion, the Sphincter pupillæ and the Ciliaris muscles.

The fibres of the oculomotor nerve arise from a nucleus which lies in the grey substance of the upper part of the floor of the cerebral aqueduct and extends in front of the aqueduct for a short distance into the floor of the third ventricle. From this nucleus the fibres pass forwards through the tegmentum, the red nucleus and the medial part of the substantia nigra, forming a series of curves with a lateral convexity, and emerge from the oculomotor sulcus on the medial side of the cerebral peduncle.

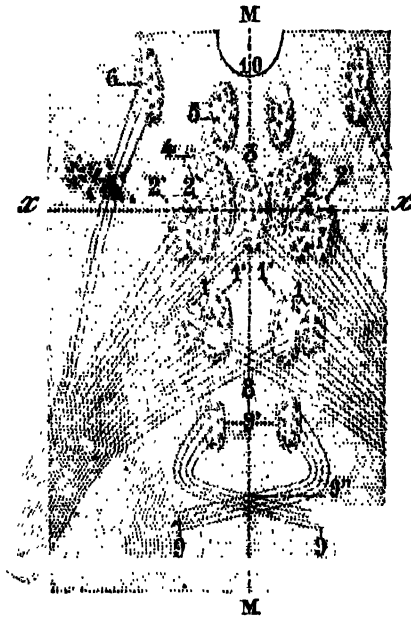
The nucleus of the oculomotor nerve does not consist of a continuous column of cells, but is broken up into a number of smaller nuclei, which are arranged in two groups, anterior and posterior. Those of the posterior group are six in number, five of which are symmetrical on the two sides of the middle line, while the sixth is centrally placed and is common to the nerves of both sides. The anterior group consists of two nuclei, an anteromedial and an anterolateral (fig. 809).

The nucleus of the nerve is said to send fibres through the medial longitudinal fasciculus to the facial nerve, for the supply of the Orbicularis oculi, Corrugator, and Frontalis muscles.* It is also connected with the nuclei of the trochlear and abducent nerves, with the cerebellum, the superior colliculus, and the cortex of the occipital lobe of the cerebrum.

The nucleus of the oculomotor nerve, considered from a physiological standpoint, can be subdivided into several smaller groups of cells, each group controlling a particular muscle. The nerves to the different muscles appear to take their origin from behind forwards as follows: Obliquus inferior, Rectus inferior, Rectus superior, Levator palpebræ superioris, and Rectus medialis; while from the anterior end of the nucleus the fibres for the Ciliaris and the Sphincter pupillæ take their origin.

On emerging from the brain, the nerve is invested with a sheath of pia mater, and enclosed in a prolongation from the arachnoid. It passes between the superior cerebellar and posterior cerebral arteries, runs forward in the triangular interval between the free and attached borders of the tentorium cerebelli, and then pierces the dura mater in front of and lateral to the posterior clinoid process. It traverses the lateral wall of the cavernous sinus, above the trochlear nerve, receiving in its course one or two filaments from the cavernous plexus of the sympathetic, and a communicating branch from the ophthalmic division of the trigeminal. It then divides into two rami, which enter the orbit through the superior orbital fissure, between the two heads of the Rectus lateralis. Here the nerve is placed below the trochlear nerve and the frontal and lacrimal branches of the ophthalmic nerve, while the nasociliary nerve is placed between its two rami.

FIG. 809.—The different groups of cells which constitute, according to Perlia, the nucleus of origin of the oculomotor and trochlear nerves. (Testut.)

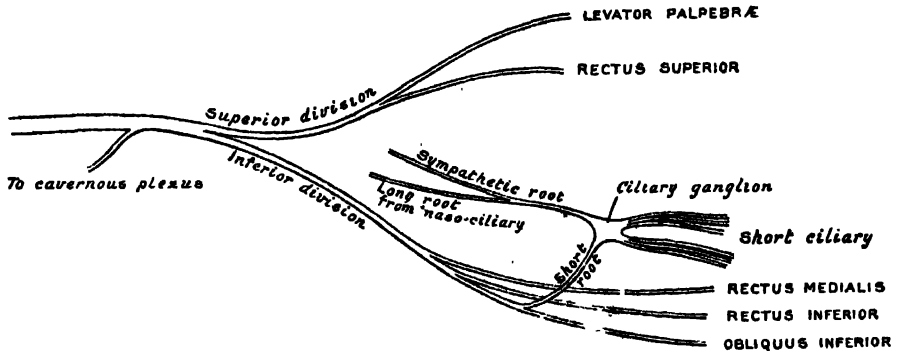


1. Posterior dorsal nucleus. 1'. Posterior ventral nucleus. 2. Anterior dorsal nucleus. 2'. Anterior ventral nucleus. 3. Central nucleus. 4. Nucleus of Edinger and Westphal. 5. Anteromedial nucleus. 6. Anterolateral nucleus. 8. Crossed fibres. 9. Trochlear nerve, with 9'. Its nucleus of origin, and 9''. Its decussation. 10. Third ventricle. M, M. Median line.

* See footnote, p. 790.

The *superior ramus*, the smaller, passes medialwards over the optic nerve, and supplies the Rectus superior and Levator palpebræ superioris. The *inferior ramus*, the larger, divides into three branches. One passes beneath the optic nerve to the Rectus medialis; another, to the Rectus inferior; the third and longest runs forwards between the Rectus inferior and Rectus lateralis to the Obliquus inferior. From the nerve to the Obliquus inferior a short thick branch is given off to the lower part of the ciliary ganglion, and forms its *short root*. All these branches enter the muscles on their ocular surfaces, with the exception of that to the Obliquus inferior, which enters the posterior border of the muscle.

FIG. 810.—A plan of the oculomotor nerve.



Applied Anatomy.—Paralysis of the oculomotor nerve may be the result of many causes, such as cerebral disease; or conditions causing pressure on the cavernous sinus; or periostitis of the bones entering into the formation of the superior orbital fissure. It results, when complete, in (1) ptosis, or drooping of the upper eyelid, in consequence of the Levator palpebræ superioris being paralysed; (2) external strabismus, on account of the unopposed action of the Rectus lateralis and Obliquus superior, which are not supplied by the oculomotor nerve and are therefore not paralysed; (3) dilatation of the pupil, because the Sphincter pupillæ is paralysed; (4) loss of power of accommodation and of contraction on exposure to light, as the Sphincter pupillæ and the Ciliaris are paralysed; (5) slight prominence of the eyeball, owing to most of its muscles being relaxed; and (6) the patient will complain of the resulting diplopia, or double vision, the false image being higher than the true, and the separation of the two images increasing with medial movements. Occasionally paralysis may affect only a part of the nerve—that is to say, there may be, for example, a dilated and fixed pupil, with ptosis, but no other signs. Irritation of the nerve causes spasm of one or other of the muscles supplied by it; thus, there may be internal strabismus from spasm of the Rectus medialis: accommodation for near objects only, from spasm of the Ciliaris; or miosis (contraction of the pupil) from irritation of the Sphincter pupillæ.

The oculomotor nerve is particularly liable to become involved in a syphilitic periarthritis, as it leaves the base of the brain, when passing between the posterior cerebral and superior cerebellar arteries; associated with locomotor ataxia various partial or complete paralyzes of the nerve are often seen.

TROCHLEAR NERVE (fig. 811)

The trochlear nerve, the smallest of the cerebral nerves, supplies the Obliquus superior oculi.

It arises from a nucleus situated in the floor of the cerebral aqueduct, opposite the upper part of the inferior colliculus. From its origin it runs downwards through the tegmentum, and then turns backwards into the upper part of the anterior medullary velum. Here it decussates with its fellow of the opposite side and emerges from the surface of the velum at the side of the frenulum veli, immediately behind the inferior colliculus.

The nerve is directed across the brachium conjunctivum cerebelli, and then winds forwards round the cerebral peduncle immediately above the pons, pierces the dura mater in the free border of the tentorium cerebelli, just behind, and lateral to, the posterior clinoid process, and passes forwards in the lateral wall of the cavernous sinus, between the oculomotor nerve and the ophthalmic division of the trigeminal. It crosses the oculomotor nerve, and enters the

orbit through the superior orbital fissure. It now becomes the highest of all the nerves, and lies medial to the frontal nerve. In the orbit it passes medialwards, above the origin of the Levator palpebræ superioris, and finally enters the orbital surface of the Obliquus superior.

In the lateral wall of the cavernous sinus the trochlear nerve forms communications with the ophthalmic division of the trigeminal and with the cavernous plexus of the sympathetic. In the superior orbital fissure it occasionally gives off a branch to the lacrimal nerve. It gives off a recurrent branch which passes backwards between the layers of the tentorium cerebelli and divides into two or three filaments which may be traced as far as the wall of the transverse sinus.

FIG. 811.—The nerves of the orbit, from above.

Applied Anatomy.—When the trochlear nerve is paralysed there is loss of function in the Obliquus superior, so that the patient is unable to turn his eye downwards and outwards. Should the patient attempt to do this, the eye of the affected side is rotated inwards, producing diplopia or double vision. Single vision exists in the whole of the field so long as the eyes look above the horizontal plane, but diplopia occurs on looking downwards. To counteract this the patient holds his head forwards, and also inclines it to the sound side.

TRIGEMINAL NERVE

The trigeminal nerve is the largest cerebral nerve. It is the sensory nerve of the face and of the greater part of the scalp, and the motor nerve of the muscles of mastication.

It is attached to the anterior or ventral surface of the pons, near its upper border, by a large *sensory*, and a small *motor*, root—the latter being placed medially and anteriorly to the former.

The fibres of the sensory root arise from the cells of the *semilunar ganglion* (Gasserian ganglion). This ganglion (figs. 811, 812) occupies a cavity (cavum Meckelii) in the dura mater covering the trigeminal impression near the apex of the petrous part of the temporal bone. The ganglion is somewhat crescentic in shape, with its convexity directed forwards and lateralwards. Medially, it is in relation with the internal carotid artery and the posterior part of the cavernous sinus. Beneath it are the motor root of the nerve and the greater superficial petrosal nerve. It receives filaments from the cavernous plexus of the sympathetic, and gives off twigs to the tentorium cerebelli.

The axis-cylinders of the cells of the semilunar ganglion divide into *peripheral* and *central* branches. The former are grouped to form the *ophthalmic* and *maxillary* nerves, and the sensory part of the *mandibular* nerve (the last is joined outside the cranium by the motor root of the nerve). The central branches constitute the fibres of the sensory root of the nerve, which leaves the concave margin of the ganglion, runs backwards and medialwards below the superior petrosal sinus and the tentorium cerebelli, and enters the pons. In the pons these fibres divide, like the fibres of the posterior roots of the spinal nerves, into ascending and descending branches. The ascending branches end



in the upper sensory nucleus of the trigeminal nerve, which is situated in the pons, on the lateral side of, and somewhat deeper than, the motor nucleus. The descending fibres form what is termed the *spinal tract* of the trigeminal nerve. This tract runs downwards through the pons into the medulla oblongata on the lateral side of a column of grey substance named the gelatinous substance of Rolando. As the tract descends, a succession of fibres leaves it and enters the gelatinous substance; the tract thus diminishes as it passes downwards, and finally ends in the upper part of the cervical portion of the medulla spinalis.

Medullation of the fibres of the sensory root begins about the fifth month of foetal life, but the whole of the fibres of the root are not medullated until the third month after birth.

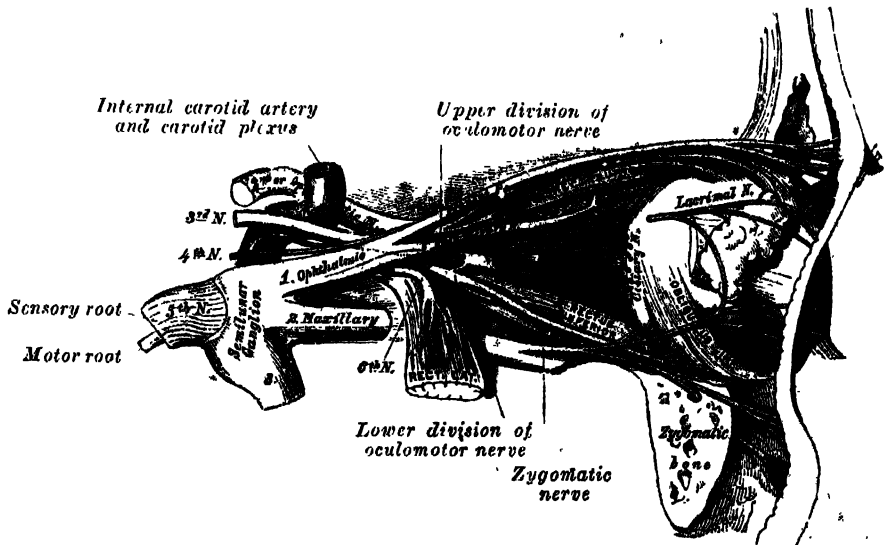
The fibres of the *motor root* arise from two nuclei, an inferior and a superior. The *inferior* or *chief nucleus* is situated in the upper part of the pons, close to its dorsal surface, and along the line of the lateral margin of the rhomboid fossa. The *superior nucleus* consists of a strand of cells occupying the whole length of the lateral portion of the grey substance of the cerebral aqueduct. The fibres from this nucleus constitute the *mesencephalic root**; they descend through the mesencephalon, and, entering the pons, join with the fibres from the lower nucleus, and the motor root, thus formed, passes forwards through the pons to its point of emergence.

Four small ganglia are associated with the three divisions of the trigeminal nerve, viz.—the *ciliary ganglion* with the ophthalmic nerve; the *sphenopalatine ganglion* with the maxillary nerve; and the *otic* and *submaxillary ganglia* with the mandibular nerve.

OPHTHALMIC NERVE (figs. 811, 812)

The **ophthalmic nerve**, or first division of the trigeminal nerve, is a sensory nerve. It supplies branches to the bulb of the eye, the lacrimal gland and

FIG. 812.—The nerves of the orbit, and the ciliary ganglion, from the side.



the conjunctiva, to a part of the mucous membrane of the nasal cavity, and to the skin of the nose, eyelids, forehead, and scalp. It is the smallest division of the trigeminal nerve, and arises from the anteromedial part of the semilunar ganglion as a flattened band, about 2.5 cm. long, which passes forwards along the lateral wall of the cavernous sinus below the oculomotor and trochlear nerves; just before entering the orbit through the superior orbital fissure, it divides into three branches, *lacrimal*, *frontal*, and *nasociliary*.

The ophthalmic nerve is joined by filaments from the cavernous plexus of

* Recent observations indicate that the mesencephalic root of the trigeminal nerve contains some sensory fibres.

OPHTHALMIC NERVE

the sympathetic, and communicates with the oculomotor, trochlear, and abducent nerves; it gives off a recurrent branch (n. tentorii), which crosses the trochlear nerve, and passes between the layers of the tentorium.

The **lacrimal nerve** is the smallest branch of the ophthalmic nerve. It sometimes receives a filament from the trochlear nerve, but possibly this consists of fibres which have previously passed from the ophthalmic to the trochlear nerve. It enters the orbit through the narrowest part of the superior orbital fissure, runs along the upper border of the Rectus lateralis, with the lacrimal artery, and communicates with the zygomatic branch of the maxillary nerve. It enters the lacrimal gland and gives off several filaments, which supply the gland and the conjunctiva. Finally it pierces the orbital septum, and ends in the skin of the upper eyelid, joining with filaments of the facial nerve.

The lacrimal nerve is occasionally absent, and its place is then taken by the zygomaticotemporal branch of the maxillary nerve. Sometimes the latter branch is absent, and a continuation of the lacrimal is substituted for it.

The **frontal nerve** is the largest branch of the ophthalmic nerve. It enters the orbit through the superior orbital fissure, and runs forwards between the Levator palpebrae superioris and the periosteum. Midway between the apex and base of the orbit it divides into two branches, a small supratrochlear and a larger supraorbital.

The **supratrochlear nerve** passes above the pulley of the Obliquus superior, and gives off a descending filament, to join the infratrochlear branch of the nasociliary nerve. It then escapes from the orbit between the pulley of the Obliquus superior and the supraorbital foramen, curves upwards on the forehead close to the bone, and sends filaments to the conjunctiva and skin of the upper eyelid; it then ascends under cover of the Corrugator and Frontalis, and divides into branches which pierce these muscles and supply the skin of the lower part of the forehead close to the middle line.

The **supraorbital nerve** passes through the supraorbital foramen, and gives off palpebral filaments to the upper eyelid. It then ascends upon the forehead, and ends in two branches, a medial and a lateral, which supply the skin of the scalp, reaching nearly as far back as the lambdoidal suture. These two branches are at first situated beneath the Frontalis; the medial branch perforates this muscle, the lateral branch pierces the galea aponeurotica. Both branches supply small twigs to the pericranium and to the mucous membrane of the frontal air-sinus.

The **nasociliary nerve** is intermediate in size between the frontal and lacrimal nerves, and is more deeply placed. It enters the orbit between the two heads of the Rectus lateralis, and between the superior and inferior rami of the oculomotor nerve. It passes across the optic nerve and runs obliquely beneath the Rectus superior and Obliquus superior, to the medial wall of the orbital cavity. Here, under the name of the *anterior ethmoidal nerve*, it passes through the anterior ethmoidal foramen and, entering the cavity of the cranium, traverses a shallow groove on the lateral margin of the front part of the lamina cribrosa of the ethmoidal bone, and runs down, through a slit at the side of the crista galli, into the nasal cavity where it lies in a groove on the inner surface of the nasal bone. It supplies *internal nasal branches* to the mucous membrane of the front part of the septum and lateral wall of the nasal cavity. Finally, it emerges, as the *external nasal branch*, between the lower border of the nasal bone and the lateral nasal cartilage, and, passing down beneath the Nasalis muscle, supplies the skin of the ala and apex of the nose.

The nasociliary nerve gives off the long root of the ciliary ganglion, the long ciliary, the infratrochlear, and the posterior ethmoidal nerves.

The *long root of the ciliary ganglion* usually arises from the nasociliary nerve between the two heads of the Rectus lateralis. It passes forwards on the lateral side of the optic nerve, and enters the posterosuperior angle of the ciliary ganglion; it is sometimes joined by a filament from the cavernous plexus of the sympathetic, or from the superior ramus of the trochlear nerve.

The *long ciliary nerves*, two or three in number, are given off from the nasociliary nerve, as it crosses the optic nerve. They accompany the short ciliary nerves from the ciliary ganglion, pierce the posterior part of the sclera, and, running forwards between it and the chorioid, are distributed to the ciliary body, iris, and cornea.

The *infratrochlear nerve* is given off from the nasociliary nerve near the anterior ethmoidal foramen. It runs forwards along the medial wall of the orbit above the upper border of the Rectus medialis, and is joined, near the pulley of the Obliquus superior, by a filament from the supratrochlear nerve. It then escapes from the orbit beneath the pulley of the Obliquus superior; it supplies the skin of the eyelids and side of the nose, the conjunctiva, lacrimal sac, and caruncula lacrimalis.

The *posterior ethmoidal nerve* leaves the orbital cavity through the posterior ethmoidal foramen and gives twigs to the ethmoidal cells and sphenoidal sinus.

Ciliary ganglion.—The ciliary ganglion (figs. 810, 812) is a small, quadrangular, flattened ganglion, of a reddish-grey colour, and about the size of a pin's head; it is situated at the back part of the orbit, in some loose fat between the optic nerve and the Rectus lateralis muscle, lying generally on the lateral side of the ophthalmic artery.

Its *roots* are three in number, and enter its posterior border. One, the long or sensory root, is derived from the nasociliary nerve, and joins its postero-superior angle. The second, the short or motor root, is a thick nerve (occasionally divided into two parts) derived from the branch of the oculomotor nerve to the Obliquus inferior, and connected with the postero-inferior angle of the ganglion. The third, the sympathetic root, is a slender filament from the cavernous plexus of the sympathetic; it is frequently blended with the long root. According to Tiedemann, the ciliary ganglion receives a twig of communication from the sphenopalatine ganglion.

Its *branches* are the short ciliary nerves. There are delicate filaments, from six to ten in number, which arise from the forepart of the ganglion in two bundles connected with its superior and inferior angles; the lower bundle is the larger. They run forwards with the ciliary arteries in a wavy course, one set above and the other below the optic nerve, and are accompanied by the long ciliary nerves. They pierce the sclera around the entrance of the optic nerve, pass forwards in delicate grooves on the inner surface of the sclera, and are distributed to the Ciliaris muscle, iris, and cornea. Tiedemann described a small branch which penetrated the optic nerve with the arteria centralis retinae.

MAXILLARY NERVE (fig. 813)

The **maxillary nerve**, or second division of the trigeminal nerve, is a sensory nerve, and is intermediate in position and size between the ophthalmic and mandibular nerves. It begins at the middle of the semilunar ganglion as a flattened plexiform band, and, passing horizontally forwards in the lower part of the lateral wall of the cavernous sinus, leaves the skull through the foramen rotundum, where it becomes more cylindrical in form and firmer in texture. It then crosses the pterygopalatine fossa, inclines lateralwards on the back of the orbital process of the palatine bone and on the back of the maxilla, and enters the orbit through the inferior orbital fissure; it traverses the infra-orbital groove and canal in the floor of the orbit, and appears on the face through the infraorbital foramen.* At its termination, the nerve lies beneath the Quadratus labii superioris, and divides into branches which are distributed to the side of the nose, the lower eyelid, and the upper lip, and join with filaments of the facial nerve.

Its *branches* may be divided into four groups, according as they are given off in the cranium, in the pterygopalatine fossa, in the infraorbital canal, or on the face.

In the cranium	Middle meningeal.
In the pterygopalatine fossa	{ Zygomatic.
	{ Sphenopalatine.
	{ Posterior superior alveolar.
In the infraorbital canal .	{ Middle superior alveolar.
	{ Anterior superior alveolar.
	{ Inferior palpebral.
On the face	{ External nasal.
	{ Superior labial.

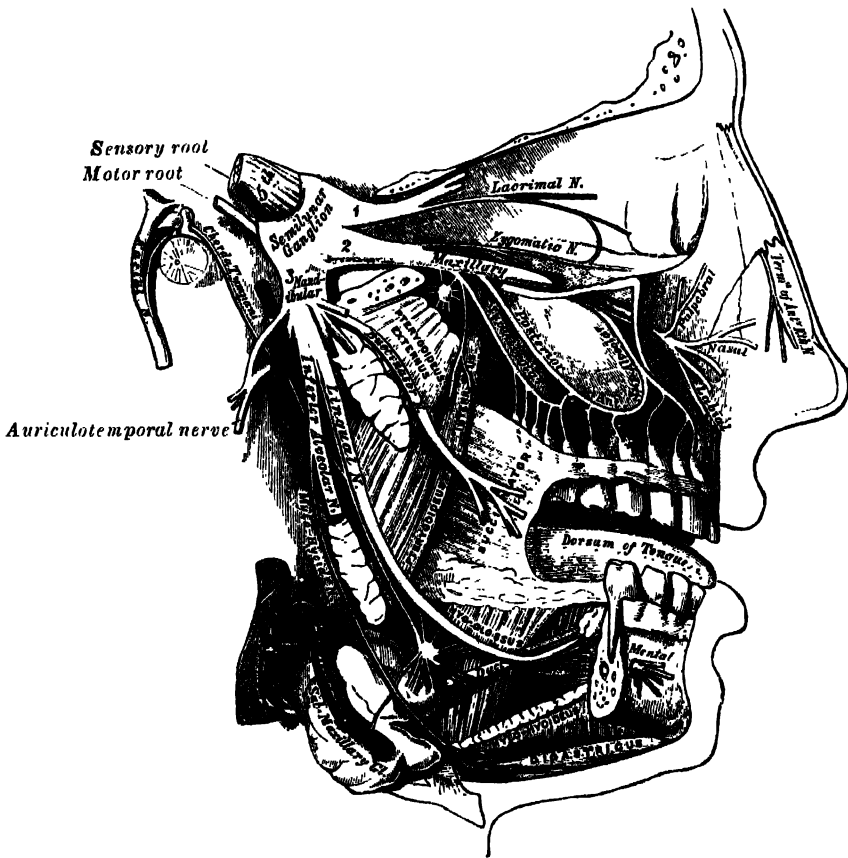
* After it enters the infraorbital canal, the nerve is frequently called the *infraorbital*.

The **middle meningeal nerve** is given off from the maxillary nerve near the semilunar ganglion; it accompanies the middle meningeal artery and supplies the dura mater.

The **zygomatic nerve** (temporomalar nerve) arises in the pterygopalatine fossa, enters the orbit by the inferior orbital fissure, and divides into two branches, zygomaticotemporal and zygomaticofacial.

The **zygomaticotemporal branch** runs along the lateral wall of the orbit in a groove in the zygomatic bone, receives a branch from the lacrimal nerve, and, passing through a canal in the zygomatic bone, enters the temporal fossa. It ascends between the temporal bone and the Temporalis muscle, pierces

FIG. 813.—The maxillary and mandibular nerves, and the submaxillary ganglion.



the temporal fascia about 2.5 cm. above the zygomatic arch, and is distributed to the skin of the side of the forehead. It communicates with the facial nerve and with the auriculotemporal branch of the mandibular nerve. As it pierces the temporal fascia, it gives off a slender twig which runs between the two layers of the fascia to the lateral angle of the orbit.

The **zygomaticofacial branch** passes along the inferolateral angle of the orbit; emerges upon the face through a foramen in the zygomatic bone, and, perforating the Orbicularis oculi, supplies the skin on the prominence of the cheek. It joins with the zygomatic branches of the facial nerve and with the inferior palpebral branches of the maxillary nerve.

The **sphenopalatine branches**, two in number; descend to the sphenopalatine ganglion.

The **posterior superior alveolar branches** arise from the maxillary nerve just before it enters the infraorbital groove; they are generally two

in number, but sometimes they arise by a single trunk. They descend on the tuberosity of the maxilla and give off several twigs to the gums and neighbouring parts of the mucous membrane of the cheek. They then enter the posterior alveolar canals on the infratemporal surface of the maxilla, and, passing forwards in the substance of the bone, communicate with the middle superior alveolar nerve, and give off branches to the lining membrane of the maxillary sinus and twigs to each molar tooth; these twigs enter the foramina at the apices of the roots of the teeth.

The **middle superior alveolar branch** is given off from the maxillary nerve in the posterior part of the infraorbital canal, and runs downwards and forwards in a canal in the lateral wall of the maxillary sinus to supply the two premolar teeth. It forms a superior dental plexus with the anterior and posterior superior alveolar branches.

The **anterior superior alveolar branch** leaves the lateral side of the maxillary nerve in the front part of the infraorbital canal, and runs in a canal in the anterior wall of the maxillary sinus. At first it curves beneath the infraorbital foramen and passes medialwards towards the nose; it then turns downwards and divides into branches which supply the incisor and canine teeth. It communicates with the middle superior alveolar branch, and gives off a *nasal branch*, which passes through a minute canal in the lateral wall of the inferior meatus, and supplies the mucous membrane of the anterior part of the inferior meatus and the floor of the nasal cavity, communicating with the nasal branches from the sphenopalatine ganglion.

The **inferior palpebral branches** ascend behind the Orbicularis oculi. They supply the skin and conjunctiva of the lower eyelid, and join with the facial and zygomaticofacial nerves at the lateral angle of the orbit.

The **external nasal branches** supply the skin of the side of the nose and of the septum mobile nasi, and join with the external nasal branch of the anterior ethmoidal nerve.

The **superior labial branches** are large and numerous: they descend behind the Quadratus labii superioris, and supply the skin of the upper lip, the mucous membrane of the mouth, and the labial glands. They are joined by branches from the facial nerve, and form with them the *infraorbital*

Sphenopalatine ganglion—The sphenopalatine ganglion (ganglion of Meckel) (fig. 814), the largest of the ganglia associated with the branches of the trigeminal nerve, is deeply placed in the pterygopalatine fossa, close to the sphenopalatine foramen. It is triangular or heart-shaped, of a reddish-grey colour, and is situated just below the maxillary nerve as it crosses the fossa. It receives sensory, motor, and sympathetic roots.

Its *sensory roots* are derived from the two sphenopalatine branches of the maxillary nerve, but most of the fibres of these branches pass directly into the palatine nerves. Its *motor root* is probably derived from the facial nerve through the greater superficial petrosal nerve, and its *sympathetic root* from the carotid plexus through the deep petrosal nerve; before entering the ganglion these two nerves join to form the nerve of the pterygoid canal.

The **greater superficial petrosal nerve** is given off from the genicular ganglion of the facial nerve; it passes through the hiatus of the facial canal, enters the cranial cavity, and runs forwards beneath the dura mater in a groove on the anterior surface of the petrous portion of the temporal bone. It then enters the cartilaginous substance which fills the foramen lacerum, and, joining with the deep petrosal branch, forms the nerve of the pterygoid canal.

The **deep petrosal nerve** is given off from the carotid plexus, and runs through the carotid canal lateral to the internal carotid artery. It then enters the cartilaginous substance which fills the foramen lacerum, and joins with the greater superficial petrosal nerve to form the nerve of the pterygoid canal.

The **nerve of the pterygoid canal** (Vidian nerve), formed by the junction of the two preceding nerves in the cartilaginous substance which fills the foramen lacerum, passes forwards through the pterygoid canal with the corresponding artery, and is joined by a small ascending *sphenoidal branch* from the otic ganglion. Finally, it enters the pterygopalatine fossa, and joins the sphenopalatine ganglion.

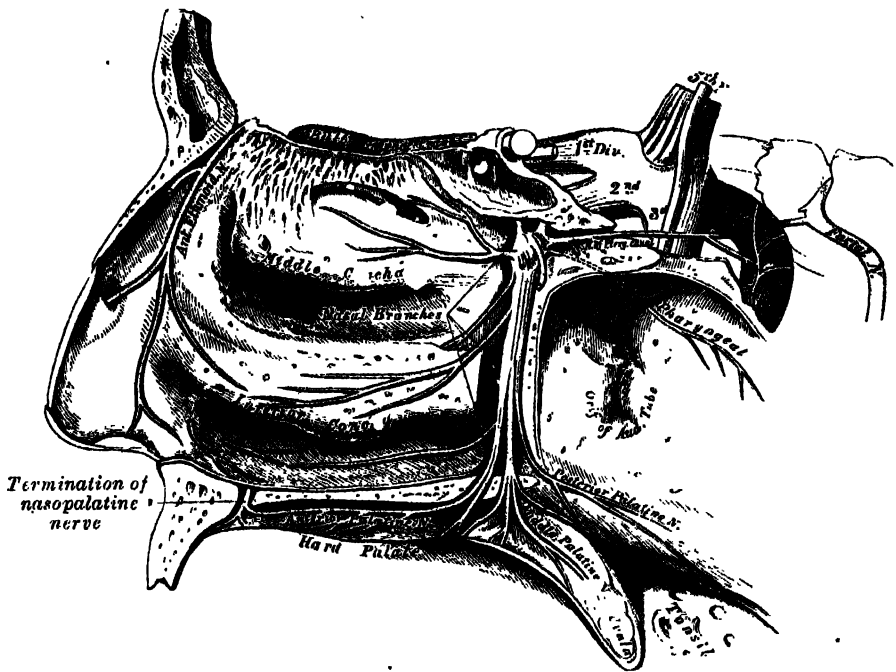
Branches of distribution.—These are divisible into four groups, viz. orbital, palatine, posterior superior nasal, and pharyngeal.

The *orbital branches* are two or three delicate filaments, which enter the orbit by the inferior orbital fissure, and supply the periosteum.

The *palatine nerves* are distributed to the roof of the mouth, the soft palate, the tonsil, and the lining membrane of the nasal cavity. Most of their fibres are derived from the sphenopalatine branches of the maxillary nerve. They are three in number: anterior, middle, and posterior.

The *anterior palatine nerve* descends through the pterygopalatine canal, emerges upon the hard palate through the greater palatine foramen, and passes forwards in a groove on the inferior surface of the hard palate, nearly as far as the incisor teeth. It supplies the gums, the mucous membrane and glands of the hard palate, and communicates in front with the terminal filaments of

FIG. 814.—The sphenopalatine ganglion and its branches.



the nasopalatine nerve. While in the pterygopalatine canal, it gives off *posterior inferior nasal branches*, which enter the nasal cavity through openings in the vertical part of the palatine bone, and ramify over the inferior nasal concha and middle and inferior meatuses; at its exit from the canal, a palatine branch is distributed to both surfaces of the soft palate.

The *middle palatine nerve* emerges through one of the lesser palatine foramina and supplies branches to the uvula, tonsil, and soft palate.

The *posterior palatine nerve* descends through the pterygopalatine canal, and emerges through one of the lesser palatine foramina; it supplies the uvula, tonsil, and soft palate. The middle and posterior palatine nerves form, with the tonsillar branches of the glossopharyngeal nerve, a plexus around the tonsil.

The *posterior superior nasal branches* enter the posterior part of the nasal cavity by the sphenopalatine foramen, and supply the mucous membrane covering the superior and middle nasal conchæ, the lining of the posterior ethmoidal cells, and the posterior part of the nasal septum. One branch, longer and larger than the others, is named the *nasopalatine nerve*. It crosses the roof of the nasal cavity below the orifice of the sphenoidal sinus, and then

runs obliquely downwards and forwards between the periosteum and mucous membrane of the lower part of the septum. It descends to the roof of the mouth through the incisive canal, and communicates with the corresponding nerve of the opposite side and with the anterior palatine nerve. It furnishes a few filaments to the mucous membrane of the nasal septum.

The *pharyngeal nerve*, a small branch, arises from the posterior part of the ganglion, passes through the pharyngeal canal with the pharyngeal branch of the internal maxillary artery, and is distributed to the mucous membrane of the nasal part of the pharynx, behind the auditory tube.

MANDIBULAR NERVE (figs. 813, 815)

The **mandibular nerve** (inferior maxillary nerve) supplies the teeth and gums of the mandible, the skin of the temporal region, the auricula, the lower lip, the lower part of the face, and the muscles of mastication; it also supplies the mucous membrane of the anterior two-thirds of the tongue. It is the largest division of the trigeminal nerve, and is made up of two roots: a large, sensory root proceeding from the inferior angle of the semilunar ganglion, and a small motor root (the motor part of the trigeminal) which passes beneath the ganglion, and unites with the sensory root, just after the exit of the latter from the foramen ovale. Immediately beneath the base of the skull, the nerve gives off from its medial side the *nervus spinosus* and the nerve to the *Pterygoideus internus*, and then divides into a small anterior, and a large posterior trunk.

The ***nervus spinosus*** enters the skull through the foramen spinosum with the middle meningeal artery. It divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura mater; the posterior branch also supplies the mucous lining of the mastoid cells; the anterior communicates with the meningeal branch of the maxillary nerve.

The **nerve to the *Pterygoideus internus*** is a slender branch which enters the deep surface of the muscle. It gives off one or two filaments to the otic ganglion.

The small anterior trunk (*nervus masticatorius*) of the mandibular nerve receives nearly the whole of the motor fibres of the trigeminal nerve, and supplies the muscles of mastication and the skin and mucous membrane of the cheek. Its branches are the masseteric, deep temporal, buccinator, and external pterygoid.

The **masseteric nerve** passes lateralwards, above the *Pterygoideus externus*, in front of the temporomandibular articulation, and behind the tendon of the *Temporalis*; it crosses the posterior part of the mandibular notch with the masseteric artery, ramifies in the deep surface of the Masseter, and gives a filament to the temporomandibular joint.

The **deep temporal nerves** are two in number, anterior and posterior. They pass above the upper border of the *Pterygoideus externus* and enter the deep surface of the *Temporalis*. The *posterior branch*, of small size, is placed at the posterior part of the temporal fossa, and sometimes arises in common with the masseteric nerve. The *anterior branch* is frequently given off from the buccinator nerve, and then ascends over the upper head of the *Pterygoideus externus*. A third or intermediate branch is often present.

The **buccinator nerve** (long buccal nerve) passes forwards between the two heads of the *Pterygoideus externus*, and downwards beneath or through the lower part of the *Temporalis*; it emerges from under the anterior border of the Masseter, ramifies on the surface of the Buccinator and unites with the buccal branches of the facial nerve. It furnishes a branch to the *Pterygoideus externus* during its passage through that muscle, and may give off the anterior deep temporal nerve. The buccinator nerve supplies the skin over the Buccinator, and the mucous membrane lining its inner surface.

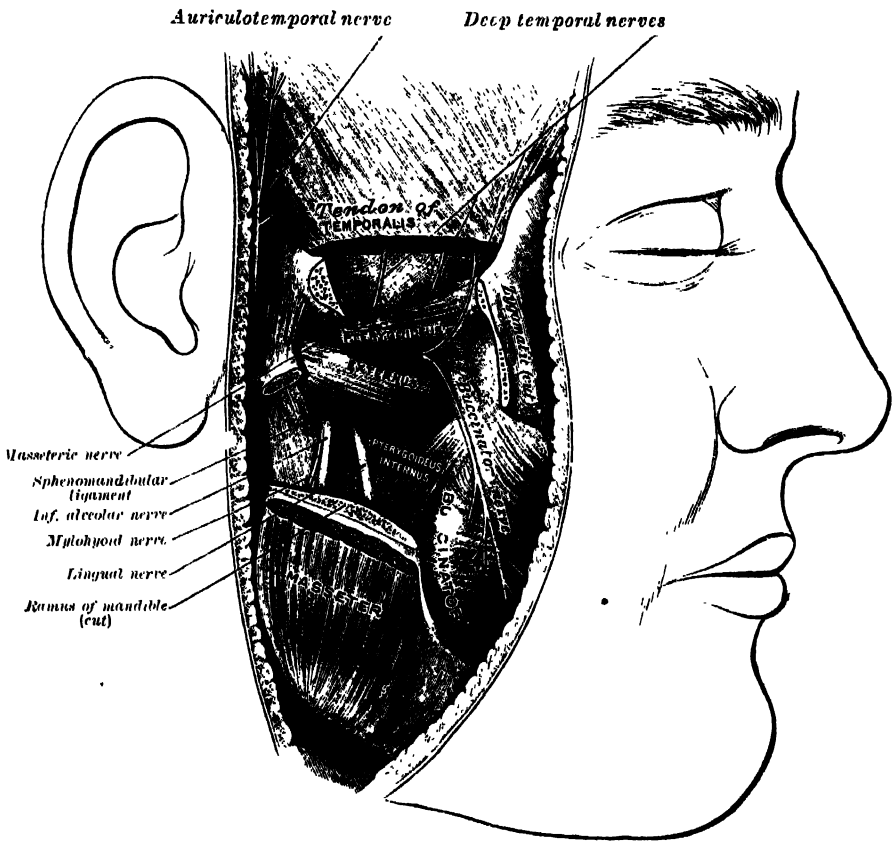
The **nerve to the *Pterygoideus externus*** enters the deep surface of the muscle. It may arise from the anterior division of the mandibular nerve or in conjunction with the buccinator nerve.

The large posterior trunk of the mandibular nerve is for the most part

sensory, but receives a few filaments from the motor root. It divides into auriculotemporal, lingual, and inferior alveolar nerves.

The **auriculotemporal nerve** generally arises by two roots, which encircle the middle meningeal artery. It runs backwards beneath the Pterygoideus externus to the medial side of the neck of the mandible. It then turns upwards with the superficial temporal artery, between the auricula and condyle of the mandible, under cover of the parotid gland; escaping from beneath the gland, it ascends over the zygomatic arch, and divides into superficial temporal branches.

FIG. 815.—The Pterygoideus externus and the branches of the mandibular nerve in relation to it.



Branches of communication.—The auriculotemporal nerve communicates with the facial nerve and with the otic ganglion. The branches to the facial, usually two in number, pass forwards from behind the neck of the mandible and join the facial nerve at the posterior border of the Masseter. The filaments to the otic ganglion are derived from the roots of the auriculotemporal nerve close to their origin.

Its branches of distribution are :

Anterior auricular.

Branches to the external acoustic meatus.

Superficial temporal.

Articular.

Parotid.

The **anterior auricular branches** are usually two in number: they supply the front of the upper part of the auricula, being distributed principally to the skin covering the front of the helix and tragus.

Branches to the external acoustic meatus, two in number, enter the meatus between its bony and cartilaginous portions, and supply the skin lining it; the upper one sends a filament to the tympanic membrane.

The *articular branches* consist of one or two twigs which enter the posterior part of the temporomandibular joint.

The *parotid branches* supply the parotid gland.

The *superficial temporal branches* accompany the superficial temporal artery and its terminal branches; they supply the skin of the temporal region and communicate with the facial and zygomaticotemporal nerves.

The *lingual nerve* lies at first beneath the Pterygoideus externus, medially to and in front of the inferior alveolar nerve, to which it is often joined by a branch which may cross the internal maxillary artery. The chorda tympani branch of the facial nerve also joins it at an acute angle in this situation. The nerve then runs between the Pterygoideus internus and the ramus of the mandible, and passes obliquely to the side of the tongue over the Constrictor pharyngis superior and Styloglossus, and then between the Hyoglossus and deep part of the submaxillary gland; it finally runs across the duct of the submaxillary gland, and along the tongue to its tip, lying immediately beneath the mucous membrane.

Branches of communication.—In addition to receiving the chorda tympani and the branch from the inferior alveolar nerve, already referred to, the lingual nerve sends two or three branches to the submaxillary ganglion, and, at the anterior margin of the Hyoglossus muscle, forms two or three loops of communication with twigs of the hypoglossal nerve.

Its *branches of distribution* supply the sublingual gland, the mucous membrane of the mouth, the gums, and the mucous membrane of the anterior two-thirds of the tongue; the terminal filaments communicate, at the tip of the tongue, with the hypoglossal nerve.

The *inferior alveolar nerve* (inferior dental nerve) is the largest branch of the mandibular nerve. It descends with the inferior alveolar artery, at first beneath the Pterygoideus externus, and then between the sphenomandibular ligament and the ramus of the mandible to the mandibular foramen. It then runs in the mandibular canal, beneath the teeth, as far as the mental foramen, where it divides into an incisive and a mental branch.

The branches of the inferior alveolar nerve are the mylohyoid, dental, incisive, and mental.

The *mylohyoid nerve* is derived from the inferior alveolar just before it enters the mandibular foramen. It descends in a groove on the deep surface of the ramus of the mandible, and reaching the under surface of the Mylohyoideus supplies this muscle and the anterior belly of the Digastricus.

The *dental branches* supply the molar and premolar teeth, and the gum. They correspond in number to the roots of those teeth; each nerve entering the orifice at the point of the root, and supplying the pulp of the tooth; above the alveolar nerve they form an inferior dental plexus.

The *incisive branch* is continued onwards within the bone, and supplies the canine and incisor teeth.

The *mental nerve* emerges at the mental foramen, and divides beneath the Triangularis muscle into three branches; one descends to the skin of the chin, and two ascend to the skin and mucous membrane of the lower lip; these branches communicate freely with the facial nerve.

Two small ganglia, the otic and the submaxillary, are connected with the mandibular nerve.

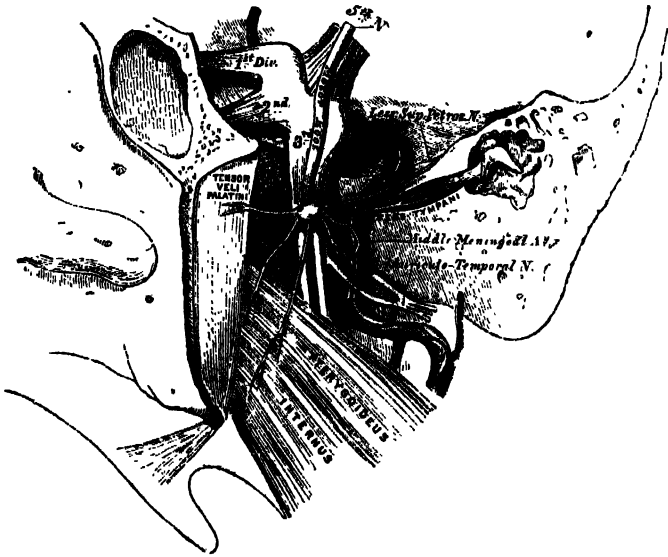
Otic ganglion.—The otic ganglion (fig. 816) is a small, oval-shaped, flattened ganglion of a reddish-grey colour, situated immediately below the foramen ovale; it lies on the medial surface of the mandibular nerve, and surrounds the origin of the nerve to the Pterygoideus internus. It is in relation, *laterally*, with the trunk of the mandibular nerve at the point where the motor and sensory roots join; *medially*, with the cartilaginous part of the auditory tube, and the origin of the Tensor veli palatini; *posteriorly*, with the middle meningeal artery.

It is connected by two or three short filaments with the nerve to the Pterygoideus internus, from which it may obtain a motor, and possibly a sensory root. It communicates with the glossopharyngeal and facial nerves, through

the lesser superficial petrosal nerve continued from the tympanic plexus, and through this nerve may receive sensory fibres from the glossopharyngeal nerve and a motor root from the facial nerve; its sympathetic root consists of a filament from the sympathetic plexus surrounding the middle meningeal artery.

Branches.—A slender filament (*sphenoidal*) ascends from the ganglion to the nerve of the pterygoid canal, and a small branch connects it with the chorda tympani nerve. Two or more branches run backwards and join the roots of the auriculotemporal nerve; these branches probably carry secretory fibres from the glossopharyngeal nerve to the parotid gland. A filament is supplied to the Tensor tympani muscle, and another to the Tensor veli palatini muscle. The former passes backwards, lateral to the auditory tube; the latter arises from the ganglion, near the origin of the nerve to the Pterygoideus internus, and is directed forwards. The fibres of these nerves are, however, mainly derived from the nerve to the Pterygoideus internus.

FIG. 816.—The otic ganglion and its branches.



Submaxillary ganglion.—The submaxillary ganglion (fig. 813) is of small size and fusiform in shape. It is situated above the deep portion of the submaxillary gland, on the Hyoglossus, near the posterior border of the Mylohyoideus. It is suspended from the lingual nerve by two filaments which join the anterior and posterior parts of the ganglion. Through the posterior filament it receives a branch from the chorda tympani nerve which runs in the sheath of the lingual. The ganglion communicates with the sympathetic by filaments from the sympathetic plexus around the external maxillary (facial) artery.

Its *branches* are five or six in number; they arise from the lower part of the ganglion, and supply the mucous membrane of the mouth, and the submaxillary gland and its duct. Fibres pass through the branch connecting the lingual nerve to the fore part of the ganglion, and are conveyed to the sublingual gland and the tongue.

Applied Anatomy.—Paralysis of the trigeminal nerve causes anaesthesia of the corresponding anterior half of the scalp, and of the face (excepting over a small area near the angle of the mandible supplied by the cervical nerves), and of the cornea and conjunctiva, and of the mucous membrane of the nose, mouth, and tongue. Taste is lost (*ageusia*) on the affected side. Paralysis and atrophy follow in the Temporalis, Masseter, and Pterygoidei, possibly also in the Tensor tympani; when the mouth is opened the mandible

is thrust over towards the paralysed side. Interference with the secretion of the tears, the nasal mucus, and the saliva, causes dryness of the corresponding mucous membranes. The sense of smell is gradually lost on the affected side from the trophic changes that follow in the nasal mucous membrane. Inflammation of the eyeball, under these circumstances known as neuromyopathic ophthalmia, is not rare, and is due to the dryness and insensitiveness of the conjunctiva; it is not a 'trophic' phenomenon, but depends on the occurrence and neglect of traumatic inflammation in the anæsthetic eye.

Trigeminal nerve reflexes.—Pains referred to various branches of the trigeminal nerve are of very frequent occurrence, and should always lead to a careful examination in order to discover a local cause. As a general rule the diffusion of pain over the various branches of the nerve is at first confined to one only of the main divisions, and the search for the causative lesion should always commence with a thorough examination of all those parts which are supplied by that division; although in severe cases pain may radiate over the branches of the other main divisions. The commonest example of this condition is the neuralgia which is so often associated with dental caries—here, although the tooth itself may not appear to be painful, the most distressing referred pains may be experienced, and these are at once relieved by treatment directed to the affected tooth.

Many other examples of trigeminal reflexes could be quoted, but it will be sufficient to mention the more common ones. Dealing with the ophthalmic nerve, severe supra-orbital pain is commonly associated with acute glaucoma or with disease of the frontal or ethmoidal air-cells. Malignant growths or empyema of the maxillary antrum, or unhealthy conditions about the inferior conchæ or the septum of the nose, are often found giving rise to 'second division' neuralgia, and should be always looked for in the absence of dental disease in the maxilla.

It is on the mandibular nerve, however, that some of the most striking reflexes are seen. It is quite common to meet with patients who complain of pain in the ear, in whom there is no sign of aural disease, and the cause is usually to be found in a carious tooth in the mandible. Moreover, with an ulcer or cancer of the tongue, often the first pain to be experienced is one which radiates to the ear and temporal fossa, over the distribution of the auriculotemporal nerve.

The trigeminal nerve is often the seat of severe neuralgia for which no local cause can be discovered; each of the three divisions has been divided, or a portion of nerve excised for this affection, usually, however, with only temporary relief. The supraorbital nerve may be exposed by making an incision 4 cm. in length along the superior orbital margin, below the eyebrow which is to be drawn upwards, the centre of the incision corresponding to the supraorbital notch. The skin and Orbicularis oculi having been divided, the nerve can be easily found emerging from the notch, and lying in some loose cellular tissue.

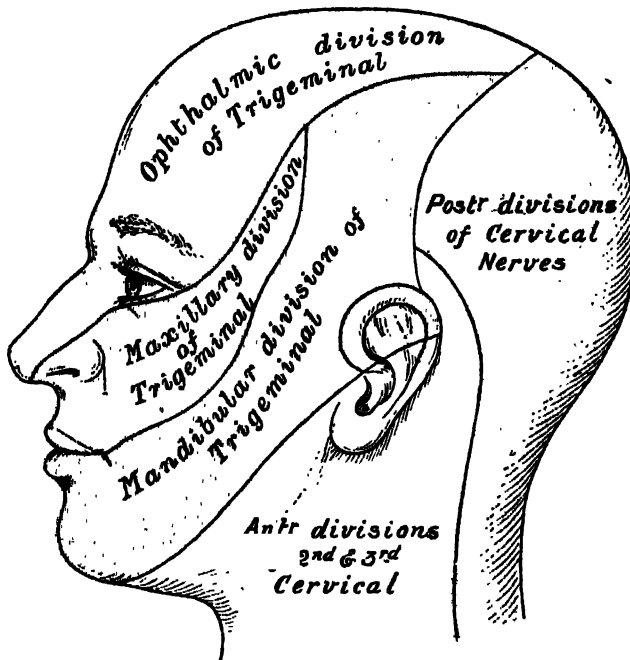
The infraorbital nerve has been divided at its exit by an incision on the cheek; or the infraorbital canal can be injected with absolute alcohol; or the whole nerve, together with the sphenopalatine ganglion as far back as the foramen rotundum, may be removed, but even then a return of the neuralgia in some other branches of the trigeminal nerve is the rule. Intracranial resection of the maxillary nerve between the semilunar ganglion and the foramen rotundum is an anatomical possibility.

The inferior alveolar nerve can be reached by a transverse incision over the ramus of the mandible placed so as to avoid injury to the facial nerve; the Masseter having been divided, a small trephine is applied to the ramus immediately beneath the mandibular notch, and, when the bone has been removed, the nerve is found lying on the Pterygoideus internus just as it enters the mandibular foramen, and it can here be resected. The lingual nerve is occasionally divided with the view of relieving the pain in cancerous disease of the tongue. This may be done in that part of its course where it lies below and behind the last molar tooth. If a line be drawn from the middle of the crown of the last molar tooth to the angle of the mandible it will cross the nerve, which lies about 1.25 cm. behind the tooth, parallel to the bulging alveolar ridge on the inner side of the body of the bone. The tongue should be pulled forwards and over to the opposite side, when the nerve can be seen standing out as a firm cord under the mucous membrane by the side of the tongue, and after division of the mucous membrane can be easily seized with a hook and a portion excised. This is a simple enough operation on the cadaver, but when the disease is extensive and has extended to the floor of the mouth, as is generally the case when the division is required, the operation is not practicable.

In severe cases of neuralgia of the trigeminal nerve, the semilunar ganglion has been removed in whole or in part with a considerable measure of success. Rose was the first to perform this operation; and he reached the ganglion by trephining the base of the skull in the position of the foramen ovale, after dividing the zygomatic arch, in front and behind, and turning it and the Masseter downwards, and cutting through the coronoid process of the mandible, and turning it and the Temporalis upwards. A more efficient method appears to be that known as the Krause-Hartley method. The bone forming the temporal fossa having been removed to a sufficient extent, the dura mater beneath the temporal lobe of the brain is gradually raised from the middle fossa, until the foramen spinosum, with the middle meningeal artery passing through it, is exposed. This vessel is to be ligatured in two places, and divided between the ligatures; and then by further raising the dura mater, the foramina ovale and rotundum will be exposed, with the man-

dibular and maxillary nerves passing through them. These nerves are to be clearly defined and divided. The dura mater is then to be raised from the ganglion, when the ophthalmic nerve will be exposed and can be divided, and the ganglion, by means of a little careful dissection, raised from its bed and removed. In some cases where the neuralgia has been limited to the maxillary nerve an intracranial resection of that nerve

FIG. 817.—A diagram showing the cutaneous nerve-areas of the face and scalp.



alone has been performed with great success. In other cases where the disease has not affected the ophthalmic division, resection of the lateral half of the ganglion only, with the maxillary and mandibular nerves, has been performed, thus leaving the sensory nerve supply to the cornea intact. The motor root is usually resected with the mandibular nerve, leading to complete paralysis of the muscles of mastication on that side.

ABDUCENT NERVE (fig. 812)

The abducent nerve supplies the Rectus lateralis oculi.

Its fibres arise from a small nucleus situated in the upper part of the rhomboid fossa, close to the middle line and beneath the colliculus facialis. They pass downwards and forwards through the pons, and emerge in the furrow between the lower border of the pons and the upper end of the pyramid of the medulla oblongata.

From the nucleus of the abducent nerve, fibres pass through the medial longitudinal fasciculus to the oculomotor nerve of the opposite side, along which they are carried to the Rectus medialis. The Rectus lateralis of one eye and the Rectus medialis of the other may therefore be said to receive their nerves from the same nucleus (fig. 818).

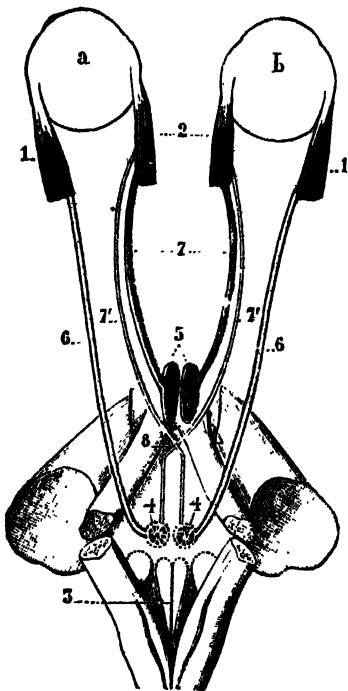
The nerve pierces the dura mater on the dorsum sellæ of the sphenoid, runs through a notch in the bone below the posterior clinoid process, and passes forwards through the cavernous sinus, on the lateral side of the internal carotid artery. It enters the orbit through the superior orbital fissure, above the ophthalmic vein, from which it is separated by a lamina of dura mater. It then passes between the two heads of the Rectus lateralis, and enters the ocular surface of that muscle.

The abducent nerve is joined by several filaments from the carotid and cavernous plexuses, and by one from the ophthalmic nerve.

The oculomotor, trochlear, ophthalmic, and abducent nerves bear certain relations to each other in the cavernous sinus, at the superior orbital fissure, and in the cavity of the orbit, as follows.

In the *cavernous sinus* (fig. 819), the oculomotor, trochlear, and ophthalmic nerves are placed in the lateral wall of the sinus, in the order given, from above downwards; the abducent nerve lies at the lateral side of the internal carotid artery. As these nerves pass forwards to the superior orbital fissure, the

FIG. 818.—A figure showing the mode of innervation of the Rectus medialis and Rectus lateralis of the eye (after Duval and Laborde). (Testut.)

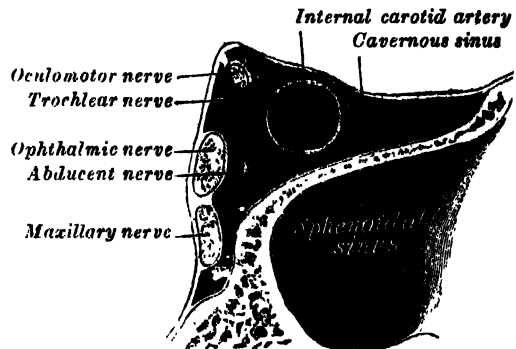


a. Left eyeball. b. Right eyeball. 1. Rectus lateralis. 2. Rectus medialis. 3. Rhomboid fossa. 4. Nucleus of abducent nerve. 5. Nucleus of oculomotor nerve. 6. Abducent nerve. 7. Nerve to Rectus medialis arising from the nucleus of the oculomotor of the same side. 7'. Nerve to Rectus medialis arising from the nucleus of the abducent of the opposite side. 8. Decussation of the fibres of the abducent nerve to the Rectus medialis.

lacrimal on the Rectus lateralis. The superior division of the oculomotor nerve lies immediately beneath the Rectus superior, while the nasociliary nerve crosses the optic nerve to reach the medial wall of the orbit. Beneath these is the optic nerve, surrounded anteriorly by the ciliary nerves, and having the ciliary ganglion on its lateral side between it and the Rectus lateralis. Below the optic nerve are the inferior division of the oculomotor nerve, and the abducent nerve, the latter lying on the medial surface of the Rectus lateralis.

Applied Anatomy.—The abducent nerve is frequently involved in fractures of the base of the skull. The result of paralysis of this nerve is medial or convergent squint. Diplopia is also present. When injured so that its function is destroyed, there is, in addition

FIG. 819.—An oblique section through the right cavernous sinus.



oculomotor and ophthalmic divide into branches, and the abducent nerve approaches the others; so that their relative positions are considerably changed.

In the *superior orbital fissure* (fig. 820), the trochlear nerve and the frontal and lacrimal divisions of the ophthalmic nerve lie in this order from the medial to the lateral side upon the same plane; they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit between the two heads of the Rectus lateralis. The superior division of the oculomotor nerve is the highest of these; beneath this lies the nasociliary branch of the ophthalmic nerve; then the inferior division of the oculomotor nerve; and the abducent nerve lowest of all.

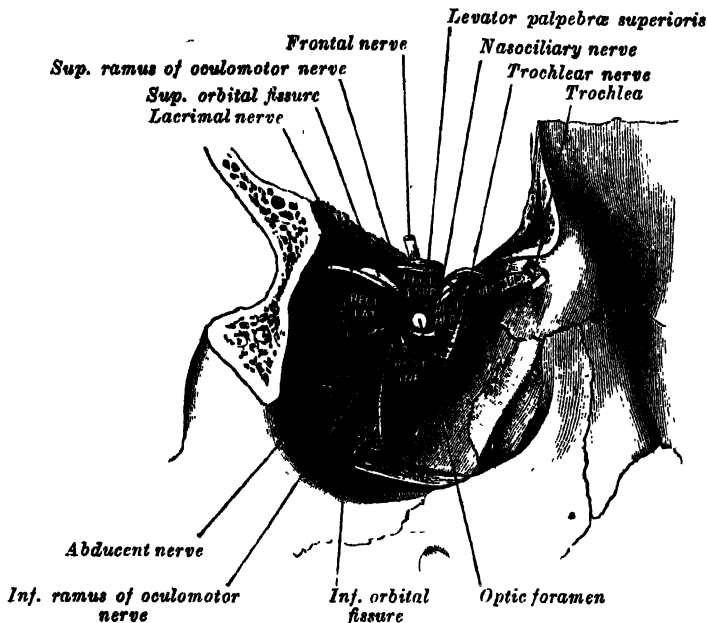
In the *orbit* (fig. 811) the trochlear, frontal, and lacrimal nerves lie immediately beneath the periosteum, the trochlear nerve resting on the Obliquus superior, the frontal on the Levator palpebræ superioris, and the

to the paralysis of the *Rectus lateralis oculi*, often a certain amount of contraction of the pupil, because some of the sympathetic fibres to the *Dilatator pupillæ* muscle are conveyed through this nerve.

FACIAL NERVE (figs. 821, 823)

The facial nerve consists of a motor and a sensory part, the latter being frequently described under the name of the *nervus intermedius* of Wrisberg (fig. 821). The two parts appear at the lower border of the pons in the recess

FIG. 820.—A dissection showing the origins of the right ocular muscles, and the nerves entering the orbit through the superior orbital fissure.



between the olive and the restiform body, the motor part being the more medial; immediately to the lateral side of the sensory part is the acoustic nerve.

The motor part supplies the muscles of the face, scalp, and auricula, the *Buccinator* and *Platysma*, the *Stapedius*, the *Stylohyoideus*, and posterior belly of the *Digastricus*; it also contains some fibres which constitute the vasodilator and secretory nerves of the submaxillary and sublingual glands, and are conveyed to these glands through the *chorda tympani* nerve. The sensory part contains the fibres of taste for the anterior two-thirds of the tongue.

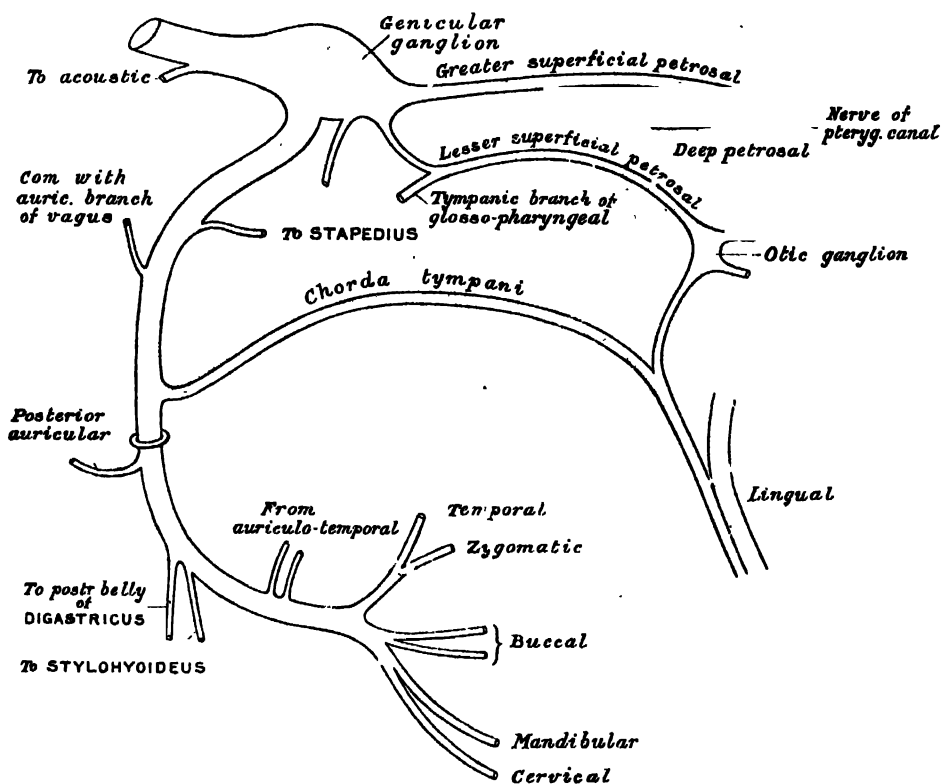
The motor root arises from a nucleus which lies deeply in the reticular formation of the lower part of the pons. This nucleus is situated above the nucleus ambiguus, behind the superior olivary nucleus, and medially to the spinal tract of the trigeminal nerve. From this origin the fibres pursue a curved course in the substance of the pons. They first pass backwards and medialwards, and, reaching the posterior end of the nucleus of the abducent nerve, run upwards close to the middle line beneath the *colliculus facialis*. At the anterior end of the nucleus of the abducent nerve they make a second bend, and run downwards and forwards through the pons to their point of emergence between the olive and the restiform body.

Some fibres from the nucleus of the oculomotor nerve are said to descend in the medial longitudinal fasciculus and join the motor root of the facial nerve before it leaves the pons. These fibres are said to supply the *Orbicularis*

oculi, Corrugator, and Frontalis, since these muscles have been observed to escape paralysis in lesions of the motor nucleus of the facial nerve.*

The *sensory* root arises from the genicular ganglion, which is situated on the geniculum of the facial nerve in the facial canal of the temporal bone. The cells of this ganglion are unipolar, and their single processes divide in a T-shaped manner into central and peripheral branches. The central branches leave the trunk of the facial nerve in the internal acoustic meatus, and form the sensory root of the nerve; the peripheral branches are continued into the chorda tympani and greater superficial petrosal nerves. Entering the brain at the lower border of the pons between the motor root and the acoustic nerve, the fibres of the sensory root of the facial nerve pass into the substance of the medulla oblongata

FIG. 821.—A plan of the facial nerve. The course of the sensory fibres is represented by the blue lines.



and end in the upper part of the terminal nucleus of the glossopharyngeal nerve and in the nerve-cells of the fasciculus solitarius (nucleus tractus solitarius).

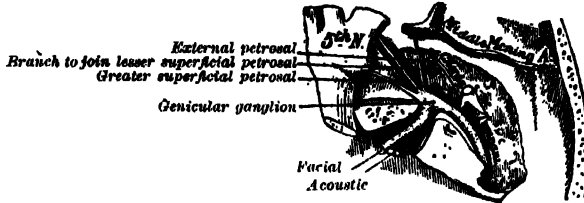
From their attachments to the brain, the two roots of the facial nerve pass lateralwards and forwards with the acoustic nerve to the opening of the internal acoustic meatus. In the meatus the motor root lies in a groove on the upper and anterior surface of the acoustic nerve, the sensory root being placed between them.

At the bottom of the meatus, the facial nerve enters the facial canal, which it traverses to its termination at the stylomastoid foramen. It is at first directed lateralwards over the vestibule, and reaching the medial wall of the epitympanic recess, it bends suddenly backwards and arches downwards behind the tympanic cavity to the stylomastoid foramen. The point where it bends suddenly backwards is named the *geniculum*; it presents a reddish gangliform swelling, the *genicular ganglion*, or nucleus of the sensory root of

* See footnote, p. 790.

the nerve (fig. 822). On emerging from the stylomastoid foramen, the facial nerve runs forwards in the substance of the parotid gland, crosses the styloid process and the external carotid artery, and divides behind the ramus of the

FIG. 822.—The course and connexions of the facial nerve in the temporal bone.



mandible into branches which form a network (*parotid plexus*) and are distributed to the superficial muscles on the side of the head, face, and upper part of the neck.

The *branches of communication* of the facial nerve may be arranged as follows :

In the internal acoustic meatus

With the acoustic nerve.

With sphenopalatine ganglion by the greater superficial petrosal nerve.

At the genicular ganglion

With the otic ganglion by a branch which joins the lesser superficial petrosal nerve.

With the sympathetic plexus on the middle meningeal artery.

In the facial canal

With the auricular branch of the vagus nerve.

At its exit from the stylomastoid foramen

With the glossopharyngeal, vagus, great auricular, and auriculotemporal nerves.

Behind the ear

With the lesser occipital nerve.

On the face

With the trigeminal nerve.

In the neck

With the cutaneous cervical nerve.

In the internal acoustic meatus some minute filaments pass from the facial nerve to the acoustic nerve.

The *greater superficial petrosal nerve* arises from the genicular ganglion of the facial nerve, and consists chiefly of sensory branches which are distributed to the mucous membrane of the soft palate ; but it probably contains a few motor fibres which form the motor root of the sphenopalatine ganglion. It passes forwards through the hiatus of the facial canal, and runs in a sulcus on the anterior surface of the petrous portion of the temporal bone beneath the semilunar ganglion, to the foramen lacerum. It receives a twig from the tympanic plexus, and in the foramen is joined by the deep petrosal nerve from the sympathetic plexus on the internal carotid artery, to form the nerve of the pterygoid canal which passes forwards through the pterygoid canal and ends in the sphenopalatine ganglion. The genicular ganglion of the facial nerve is connected with the otic ganglion by a branch which joins the lesser superficial petrosal nerve, and also with the sympathetic filaments accompanying the middle meningeal artery. According to Arnold, a twig passes back from the ganglion to the acoustic nerve. Just before the facial nerve emerges from the stylomastoid foramen, it generally receives a twig from the auricular branch of the vagus.

After its exit from the stylomastoid foramen, the facial nerve sends a twig to the glossopharyngeal nerve, and communicates with the auricular branch of the vagus nerve, with the great auricular nerve of the cervical plexus, with the auriculotemporal nerve in the parotid gland, with the lesser occipital nerve behind the ear, with the terminal branches of the trigeminal nerve on the face, and with the cutaneous cervical nerve in the neck.

The *branches of distribution* (figs. 821, 823) of the facial nerve may be thus arranged :

Within the facial canal	{ Nerve to the Stapedius muscle.
	{ Chorda tympani.
At its exit from the stylo-	{ Posterior auricular.
mastoid foramen	Digastric.
	Stylohyoid.
	Temporal.
	Zygomatic.
On the face	Buccal.
	Mandibular.
	Cervical.

The nerve to the Stapedius arises opposite the pyramidal eminence on the posterior wall of the tympanic cavity (p. 987); it passes forwards through a small canal to reach the muscle.

The *chorda tympani nerve* is given off from the facial nerve about 6 mm. above the stylomastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through an aperture (*iter chordæ posterioris*) on its posterior wall, close to the posterior border of the medial surface of the tympanic membrane and on a level with the upper end of the manubrium of the malleus. It traverses the tympanic cavity, between the fibrous and mucous layers of the tympanic membrane, crosses the manubrium of the malleus, and leaves the cavity through a foramen situated at the inner end of the petrotympanic fissure, and named the *iter chordæ anterioris*, or *canal of Huguier*. It runs downwards and forwards between the Pterygoidei externus and internus on the medial surface of the spina angularis of the sphenoid (which it sometimes grooves) and on the medial surface of the Pterygoideus externus, where it joins, at an acute angle, the posterior border of the lingual nerve. It contains a few efferent fibres which enter the submaxillary ganglion, and through it are distributed to the submaxillary and sublingual glands; the majority of the fibres are afferent, and are continued onwards through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds; they constitute the nerve of taste for this portion of the tongue. Before uniting with the lingual nerve the chorda tympani is joined by a small branch from the otic ganglion.

The *posterior auricular nerve* arises close to the stylomastoid foramen, and runs upwards in front of the mastoid process; here it is joined by a filament from the auricular branch of the vagus nerve, and communicates with the posterior branch of the great auricular nerve, and with the lesser occipital nerve. As it ascends between the external acoustic meatus and mastoid process it divides into an auricular and an occipital branch. The *auricular branch* supplies the Auricularis posterior and the intrinsic muscles on the cranial surface of the auricula. The *occipital branch*, the larger, passes backwards along the superior nuchal line of the occipital bone, and supplies the Occipitalis.

The *digastric branch* arises close to the stylomastoid foramen, and divides into several filaments which supply the posterior belly of the Digastricus; one of these filaments joins the glossopharyngeal nerve.

The *stylohyoid branch* frequently arises in conjunction with the digastric branch; it is long and slender, and enters the Stylohyoideus about its middle.

The *temporal branches* cross the zygomatic arch to the temporal region. They supply the Auricularis anterior and Auricularis superior, and join with the zygomaticotemporal branch of the maxillary nerve, and with the auriculo-temporal branch of the mandibular nerve. The more anterior branches supply the Frontalis, the Orbicularis oculi, and the Corrugator, and join the supra-orbital and lacrimal branches of the ophthalmic nerve.

The *zygomatic branches* run across the zygomatic bone to the lateral angle of the orbit; they supply the Orbicularis oculi, and join with filaments of the lacrimal nerve and the zygomaticofacial branch of the maxillary nerve.

The *buccal branches* pass horizontally forwards to be distributed below the orbit and around the mouth. The *superficial branches* run beneath the skin and above the superficial muscles of the face, which they supply; some are distributed to the Procerus, joining at the medial angle of the orbit with

the infratrochlear and anterior ethmoidal nerves. The *deep branches* pass beneath the Zygomaticus and the Quadratus labii superioris, supplying them and forming an *infraorbital plexus* with the superior lateral branches of the infraorbital nerve; these branches also supply the small muscles of the nose. The lower deep branches supply the Buccinator and Orbicularis oris, and join with filaments of the buccinator branch of the mandibular nerve.

The mandibular branch (ramus marginalis mandibulæ) passes forwards beneath the Platysma and Triangularis, supplies the muscles of the lower lip

FIG. 823.—The nerves of the scalp, face, and side of neck.



and chin, and communicates with the mental branch of the inferior alveolar nerve.

The *cervical branch* (ramus colli) runs forwards beneath the Platysma across the side of the neck over the suprahyoid region. It supplies the Platysma and communicates with the cervical cutaneous nerve.

Applied Anatomy.—Facial palsy is commonly unilateral, and may be either: (1) *peripheral*, from lesion of the facial nerve; (2) *nuclear*, from destruction of the facial nucleus; or (3) *central, cerebral, or supranuclear*, from injury in the brain to the fibres passing from the cortex through the internal capsule to the facial nucleus, or from injury to the face-area of the motor cortex itself. In supranuclear facial paralysis, which is usually part of a hemiplegia; it is the lower part of the face that is chiefly affected, while the forehead can be freely wrinkled on the palsied side, the eye can be closed fairly well, and

the eyeball is not rolled up under the upper lid; emotional movements of the face are much better executed than voluntary; and the electrical reactions of the muscles on the affected side are not altered. If the paralysis is due to lesion of the facial nucleus, the Orbicularis oris escapes, as the nuclear origin of the nerve to this muscle seems to be connected with that of the tongue-nerves; otherwise the symptoms are identical with those of the common peripheral facial palsy, of which several types may be distinguished according to the point in its course at which the facial nerve is injured. If the lesion occurs (a) in the pons, facial paralysis is produced as in (d) below; taste and hearing are not affected, but the abducent nerve also will be paralysed because the fibres of the facial nerve loop round its nucleus in the pons. When the nerve is paralysed (b) in the petrous bone, in addition to the paralysis of the muscles of expression, there is loss of taste in the anterior part of the tongue, and the patient is unable, from involvement of the chorda tympani, to recognise the difference between bitters and sweets, acids and salines. The mouth is dry, because the salivary glands are not secreting; and the sense of hearing is affected from paralysis of the Stapedius. When the cause of the paralysis is (c) fracture of the base of the skull, the acoustic and petrosal nerves are usually involved. But by far the commonest cause of facial palsy is (d) exposure of the nerve to cold or injury at or after its exit from the stylomastoid foramen (Bell's paralysis). In these cases the face looks asymmetrical even when at rest, and more so in the old than in the young. The affected side of the face and forehead remains motionless when voluntary or emotional movement is attempted. The lines on the forehead are smoothed out, the eye can be shut only by hand, tears fail to enter the lacrimal puncta because they are no longer in contact with the conjunctiva, the conjunctival reflex is absent, and efforts to close the eye merely cause the eyeball to roll upwards until the cornea lies under the upper lid. The tip of the nose is drawn over towards the sound side; the nasolabial fold is partially obliterated on the affected side, and the ala nasi does not move properly on respiration. The lips remain in contact on the paralysed side, and cannot be put together for whistling; when a smile is attempted the angle of the mouth is drawn up on the unaffected side; on the affected side the lips remain nearly closed, and the mouth assumes a characteristic triangular form. During mastication food accumulates in the cheek, from paralysis of the Buccinator, and dribbles or is pushed out from between the paralysed lips. On protrusion the tongue seems to be thrust over towards the palsied side, but verification of its position by reference to the incisor teeth will show that this is not really so. The Platysma and the muscles of the auricula are paralysed; in severe cases the articulation of labials is impaired. The electrical reactions of the affected muscles are altered (reaction of degeneration), and the degree to which this alteration has taken place after a week or ten days gives a valuable guide to the prognosis. Most cases of Bell's palsy recover completely.

The facial nerve is at fault in cases of so-called 'histrionic spasm,' which consists in an almost constant and uncontrollable twitching of some or all of the muscles of the face. This twitching is sometimes so severe as to cause great discomfort and annoyance to the patient, and to interfere with sleep, and for its relief the facial nerve has been stretched. The operation is performed by making an incision behind the ear, from the root of the mastoid process to the angle of the mandible. The parotid is turned forwards and the dissection carried along the anterior border of the Sternocleidomastoideus and mastoid process, until the upper border of the posterior belly of the Digastricus is found. The nerve is parallel to this on about the level of the middle of the mastoid process. When found, the nerve must be stretched by passing a blunt hook beneath it and pulling it forwards and outwards. Too great force must not be used, for fear of permanent injury to the nerve.

ACOUSTIC NERVE

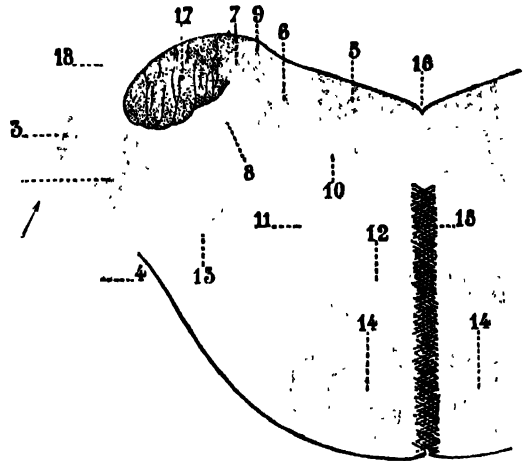
The acoustic nerve appears in the groove between the pons and medulla, behind the facial nerve and in front of the restiform body; it is distributed exclusively to the internal ear. It consists of two sets of fibres, which, although differing in their central connexions, are both concerned in the transmission of afferent impulses from the internal ear to the medulla oblongata and pons, and from there, by means of fibres which arise from collections of grey substance in these structures, to the cerebrum and cerebellum. One set of fibres forms the vestibular nerve, and arises from the cells of the vestibular ganglion situated in the internal acoustic meatus; the other set constitutes the cochlear nerve, and takes origin from the cells of the spiral ganglion of the cochlea. Both nerve-ganglia consist of bipolar nerve-cells, and from each cell a central fibre passes to the brain, and a peripheral fibre to the internal ear.

Vestibular nerve (fig. 824).—The fibres of the vestibular nerve enter the brain medially to, and on a higher level than, those of the cochlear nerve. They pass backwards through the pons between the restiform body and the spinal tract of the trigeminal nerve and divide into ascending and descending branches

ACOUSTIC NERVE

which mostly end in the vestibular nuclei. These nuclei consist of: (1) The *medial* or *chief nucleus*, situated in the area acustica of the rhomboid fossa: this nucleus is triangular on transverse section and is crossed dorsally by the *striæ medullares* (*striæ acusticæ*); the downward prolongation of the medial nucleus constitutes (2) the *descending* or *spinal nucleus*. (3) The *lateral nucleus* (nucleus of Deiters), and (4) the *superior nucleus* (nucleus of Bechterew) lie close to the restiform body, and the former contains large multipolar cells. The descending branches of the vestibular nerve end around the cells of the medial and spinal nuclei and constitute the *spinal root* of the nerve. An important strand of descending fibres, the vestibulospinal fasciculus, springs from the cells of Deiters' nucleus and runs downwards in the anterior funiculus of the medulla spinalis (p. 755); it probably conveys impulses to the motor cells of the medulla spinalis. Most of the ascending fibres end in the vestibular nuclei, but some pass directly to the roof nucleus (nucleus fastigii) and cortex of the opposite side of the cerebellum: these direct fibres are accompanied by others which originate in the cells of the vestibular nuclei. From the cells of the vestibular nuclei fibres ascend in the medial longitudinal fasciculus and end in the nuclei of the oculomotor, trochlear and abducent nerves, while others probably reach the thalamus through the lateral lemniscus.

FIG. 824.—The terminal nuclei of the vestibular nerve. (Schematic.) (Testut.)



1. Cochlear nerve. 2. Accessory cochlear nucleus. 3. Lateral cochlear nucleus. 4. Vestibular nerve. 5. Medial or chief vestibular nucleus. 6. Nucleus of Deiters. 7. Nucleus of Bechterew. 8. Descending fibres of vestibular nerve. 9. Fibres passing to cerebellum. 10. Fibres going to raphe. 11. Fibres taking an oblique course. 12. Lemniscus. 13. Spinal tract of trigeminal. 14. Cerebrospinal fasciculus. 15. Raphe. 16. Fourth ventricle. 17. Restiform body. 18. Origin of striæ medullares.

Cochlear nerve (fig. 825).

—The cochlear nerve is placed laterally to the vestibular nerve. Its fibres end in two nuclei: one, the *accessory cochlear nucleus*, lies in front of the restiform body; the other, the *lateral cochlear nucleus*, on the lateral side of the restiform body.

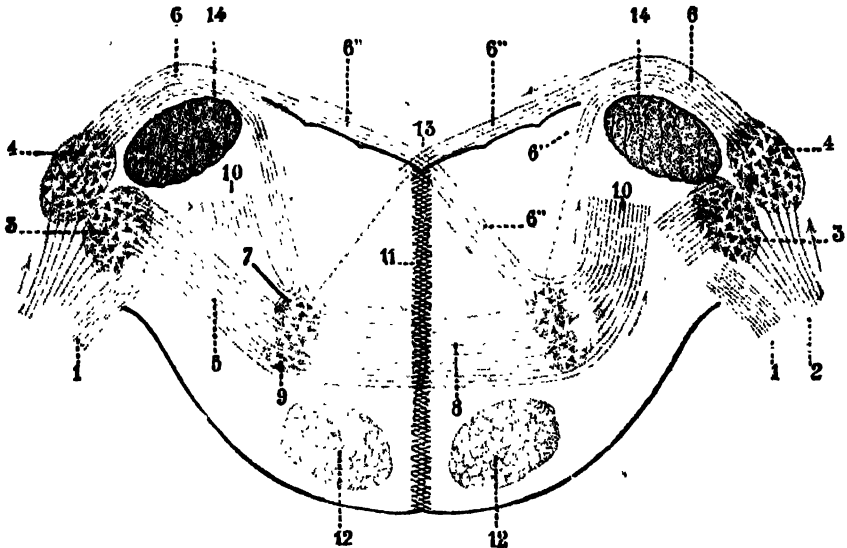
The *striæ medullares* (*striæ acusticæ*) are the axons of cells of the lateral cochlear nucleus. They pass over the restiform body, and across the rhomboid fossa to the median sulcus. Here they dip into the substance of the pons, to end around the cells of the superior olivary nuclei of both sides. There are, however, other fibres, and these are both direct and crossed, which pass into the lateral lemniscus. The cells of the accessory cochlear nucleus give origin to fibres which run transversely in the pons and constitute the trapezium; some of these fibres end around the cells of the superior olivary nucleus or of the trapezoid nucleus of the same or opposite side, while others, crossed or uncrossed, pass directly into the lateral lemniscus.

If the further connexions of the cochlear nerve of one side, say the left, be considered, it is found that they lie lateral to the main sensory tract, the lemniscus, and are therefore termed the *lateral lemniscus*. The fibres comprising the left lateral lemniscus arise in the superior olivary and trapezoid nuclei of the same or opposite side, while others are the uninterrupted fibres already alluded to, and these are either crossed or uncrossed, the former being the axons of the cells of the right accessory and right lateral nuclei, while the latter are derived from the cells of the left nuclei. In the upper part of the lateral lemniscus there is a collection of nerve-cells, the *nucleus of the lateral lemniscus*, around the cells of which some of the fibres arborise, and from the cells of which axons originate and are continued upwards into the tract of

the lateral lemniscus. The ultimate ending of the lateral lemniscus is partly in the medial geniculate body, and partly in the inferior colliculi. From the cells of these bodies new fibres arise and ascend in the occipital part of the internal capsule to reach the posterior three-fifths of the superior temporal gyrus and the transverse temporal gyri.

The acoustic nerve contains a few efferent fibres which arise in the quadrigeminal bodies, the nucleus of the lateral lemniscus, the superior olivary, and trapezoid nuclei.

FIG. 825.—The terminal nuclei of the cochlear nerve. (Schematic.) (Testut.)



The vestibular nerve with its terminal nuclei and their efferent fibres have been suppressed. On the other hand, in order not to obscure the trapezoid body, the efferent fibres of the terminal nuclei on the right side have been resected in a considerable portion of their extent. The trapezoid body, therefore, shows only one-half of its fibres, viz. those which come from the left.

1. Vestibular nerve, divided at its entrance into the medulla oblongata. 2. Cochlear nerve. 3. Ventral or accessory cochlear nucleus. 4. Lateral cochlear nucleus. 5. Efferent fibres of accessory cochlear nucleus. 6. Efferent fibres of lateral cochlear nucleus, forming the stria medullares, with 6', their direct bundle going to the superior olivary nucleus of the same side, 6'', their decussating bundles going to the superior olivary nucleus of the opposite side. 7. Superior olivary nucleus. 8. Trapezoid body. 9. Trapezoid nucleus. 10. Ventral acoustic tract (lateral lemniscus). 11. Raphe. 12. Cerebrosplinal fasciculus. 13. Fourth ventricle. 14. Restiform body.

The acoustic nerve is soft in texture, and destitute of neurolemma. After leaving the medulla oblongata it passes forwards across the posterior border of the brachium pontis, in company with the facial nerve, from which it is partially separated by the internal auditory artery. It then enters the internal acoustic meatus with the facial nerve. At the bottom of the meatus it receives one or two filaments from the facial nerve, and divides into its two branches, *cochlear* and *vestibular*, the distribution of which will be described with the anatomy of the internal ear.

Applied Anatomy.—The acoustic nerve is frequently injured, together with the facial nerve, in fracture of the middle fossa of the base of the skull implicating the internal acoustic meatus. The nerve may be either torn across, producing permanent deafness, or it may be bruised or pressed upon by extravasated blood or inflammatory exudation, when the deafness will in all probability be temporary. The nerve may also be injured by violent blows on the head without any fracture of the bones of the skull taking place, and deafness may arise from loud explosions from dynamite, &c., probably from some lesion of this nerve, which is more liable to be injured than the other cerebral nerves on account of its structure. 'Nerve-deafness,' as contrasted with deafness due to changes in the middle ear or meatus, is suggested if (1) a sounding tuning-fork placed on the middle-line of the head is heard better (Weber's test) by the unaffected ear; or if (2) the sounding tuning-fork is heard longer when held before the affected ear (=air conduction) than when it is stood on the corresponding mastoid (=bone conduction, Rinne's test); or if (3) the sounding tuning-fork applied to the vertex or mastoid is heard less well when the air in the meatus is compressed by the use of a Siegle's speculum (Gallé's test); or

If (4) the tuning-fork placed on the mastoid is heard for a shorter time than its sound is perceptible to a normal individual (=evidence that bone conduction is diminished, Schwabach's test). It must be remembered that all these tests are liable to anomalies and exceptions, and are not applicable to old people. If, however, concordant results are yielded by the tests of Weber, Rinne, and Gellé, Bezold's 'triad of symptoms,' nerve-deafness rather than deafness due to disease of the conducting structures, is rendered highly probable.

Tinnitus aurium, or the hearing of sounds in the ear that have no objective cause outside the body, is said to be present in as many as sixty per cent. of cases of ear disease of all sorts, and is commonest in disease of the labyrinth or of the nerve. It is very variable in intensity; the worst forms are purely subjective and due to irritation of the nerve itself. The sounds heard are of the most varied nature—buzzing, hissing, whistling, rushing, bell-ringing, and so forth—and may occupy the patient's attention so completely that he is no longer able to attend to his business; he may even commit suicide in order to escape from them. In the insane, tinnitus is associated with delusions and hallucinations of hearing; cases of insanity have even been recorded in which cure was effected by the removal of cerumen impacted in the meatus and giving rise to persistent tinnitus.

GLOSSOPHARYNGEAL NERVE (figs. 826, 827, 828)

The glossopharyngeal nerve contains motor and sensory fibres, and is distributed, as its name implies, to the tongue and pharynx. It is the nerve of ordinary sensation to the mucous membrane of the pharynx, fauces, and palatine tonsil, and the nerve of taste to the posterior part of the tongue. It is attached by three or four filaments to the upper part of the medulla oblongata, in the groove between the olive and the restiform body.

The *sensory* fibres arise from the cells of the superior and petrous ganglia, which are situated on the trunk of the nerve, and will be presently described. When traced into the medulla, some of the sensory fibres end by arborising around the cells of the upper part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa. Most of them, however, contribute to form a strand, named the *fasciculus solitarius*, which descends in the medulla oblongata. Associated with this strand are numerous nerve-cells (*nucleus tractus solitarii*) and around these cells the fibres of the fasciculus end.

The *motor* fibres spring from the cells of the *nucleus ambiguus*, which lies some distance from the surface of the rhomboid fossa in the lateral part of the medulla and is continuous below with the anterior grey column of the medulla spinalis. From this nucleus the fibres are first directed backwards towards the rhomboid fossa, and then forwards and lateralwards to join with the fibres of the sensory root.

(The nucleus ambiguus gives origin to the motor branches of the glossopharyngeal and vagus nerves, and to the cerebral part of the accessory nerve.)

From the medulla oblongata, the glossopharyngeal nerve passes lateralwards across the flocculus of the cerebellum, and leaves the skull through the central part of the jugular foramen laterally to and in front of the vagus and accessory nerves and in a separate sheath of dura mater (fig. 827). In its passage through the jugular foramen, it grooves the lower border of the petrous part of the temporal bone, and, at its exit from the skull, passes forwards between the internal jugular vein and internal carotid artery; it descends in front of the latter vessel, and beneath the styloid process and the muscles connected with it, to the lower border of the Stylopharyngeus. It then curves forwards, forming an arch on the side of the neck and lying upon the Stylopharyngeus and Constrictor pharyngis medius. Thence it passes under cover of the Hyoglossus, and is finally distributed to the palatine tonsil, the mucous membrane of the fauces and base of the tongue, and the mucous glands of the mouth.

Two ganglia, the superior and the petrous, are situated on that portion of the nerve which traverses the jugular foramen (fig. 826).

The superior ganglion (jugular ganglion) is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is very small, and is usually regarded as a detached portion of the petrous ganglion.

The petrous ganglion is larger than the superior ganglion and is situated in a depression in the lower border of the petrous portion of the temporal bone.

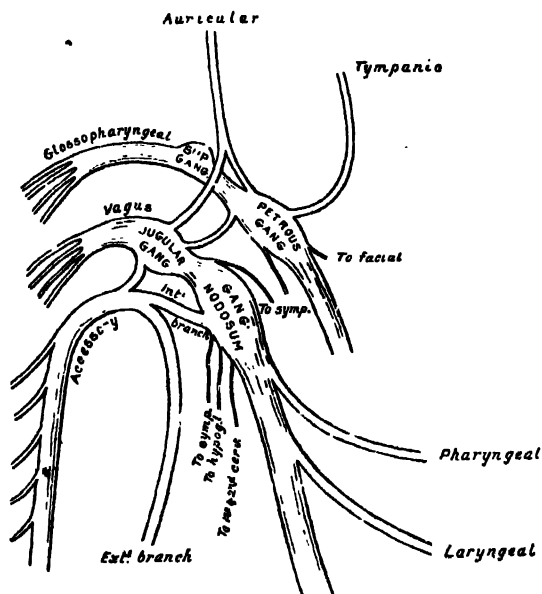
Branches of communication.—The glossopharyngeal nerve communicates with the sympathetic trunk and with the vagus and facial nerves.

The petrous ganglion is connected by a filament with the superior cervical ganglion of the sympathetic. The branches to the vagus consist of two filaments which arise from the petrous ganglion; one passes to the auricular branch, and the other to the jugular ganglion of the vagus. The branch of communication with the facial arises from the trunk of the glossopharyngeal nerve below the petrous ganglion; it perforates the posterior belly of the Digastricus and joins the facial nerve near the stylomastoid foramen.

The *branches of distribution* of the glossopharyngeal are: tympanic, carotid, pharyngeal, muscular, tonsillar, and lingual.

The **tympanic nerve** (Jacobson's nerve) arises from the petrous ganglion of the glossopharyngeal nerve, and ascends to the tympanic cavity through the inferior tympanic canaliculus (p. 208). In the tympanic cavity it divides

FIG. 826.—A plan of the upper portions of the glossopharyngeal, vagus, and accessory nerves.



into branches which form the *tympanic plexus* and are contained in grooves upon the surface of the promontory. This plexus gives off: (1) the lesser superficial petrosal nerve; (2) a branch to join the greater superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which will be described in connexion with the anatomy of the middle ear.

The **carotid branches** descend along the trunk of the internal carotid artery as far as its origin, communicating with the pharyngeal branch of the vagus, and with branches of the sympathetic.

The **pharyngeal branches** are three or four filaments which unite, opposite the Constrictor pharyngis medius, with the pharyngeal branches of the vagus and the laryngopharyngeal branches of the sympathetic trunk to form the *pharyngeal plexus*; branches from this plexus perforate the muscular coat of the pharynx and supply its muscles and mucous membrane.

The **muscular branch** is distributed to the Stylopharyngeus.

The **tonsillar branches** supply the palatine tonsil, and form around it a plexus with branches of the middle and posterior palatine nerves; from this plexus filaments are distributed to the soft palate and fauces.

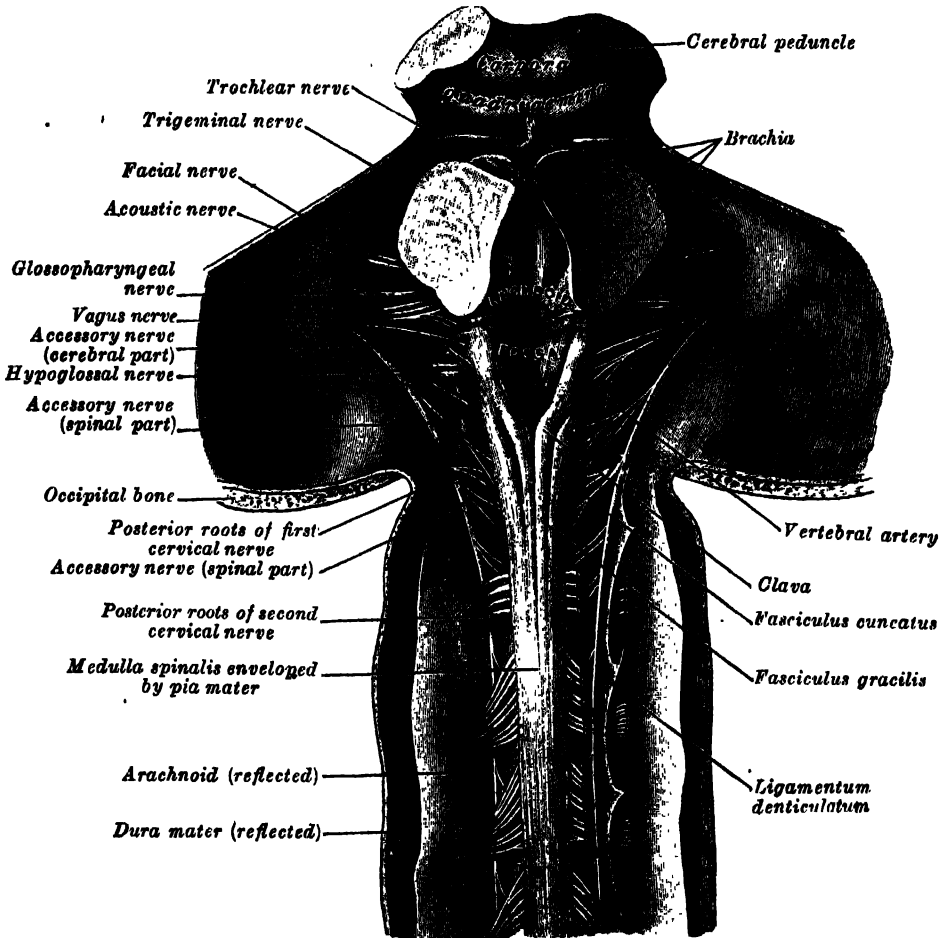
The **lingual branches** are two in number: one supplies the papillæ vallatæ and the mucous membrane covering the base of the tongue; the other supplies the mucous membrane and follicular glands of the posterior part of the tongue, and communicates with the lingual nerve.

VAGUS NERVE (figs. 826, 827, 828)

The **vagus nerve** is composed of motor and sensory fibres, and has a more extensive course and distribution than any of the other cerebral nerves, since it passes through the neck and thorax to the abdomen.

The **vagus nerve** is attached by eight or ten filaments to the medulla oblongata in the groove between the olive and the restiform body, below the glossopharyngeal nerve. The *sensory* fibres arise from the cells of the jugular

FIG. 827.—The upper part of the medulla spinalis, and the hind- and mid-brains; exposed from behind.



ganglion and ganglion nodosum of the nerve (p. 878), and, when traced into the medulla oblongata, mostly end by arborising around the cells of the inferior part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa; a few descend in the fasciculus solitarius and end around its cells. The *motor* fibres arise from the cells of the nucleus ambiguus, already referred to in connexion with the motor root of the glossopharyngeal nerve (p. 875).

The filaments of the nerve unite, and form a flat cord which passes beneath the flocculus of the cerebellum to the jugular foramen, through which it leaves the cranium. In emerging through this opening, the vagus nerve is accompanied by and contained in the same sheath of dura mater with the accessory nerve, a septum separating them from the glossopharyngeal nerve which lies

in front (fig. 827). In this situation the vagus nerve presents a well-marked ganglionic enlargement, which is called the *jugular ganglion* (ganglion of the root); to it the accessory nerve is connected by one or two filaments. After its exit from the jugular foramen the vagus nerve is joined by the cerebral portion of the accessory nerve, and enlarges into a second gangliform swelling, called the *ganglion nodosum* (ganglion of the trunk); through this the fibres of the cerebral portion of the accessory nerve pass without interruption, being principally distributed to the pharyngeal and superior laryngeal branches of the vagus nerve, but some of its fibres descend in the trunk of the vagus nerve, to be distributed with the recurrent nerve and probably also with the cardiac nerves.

The vagus nerve passes vertically down the neck within the carotid sheath, lying between the internal jugular vein and internal carotid artery as far as the upper border of the thyroid cartilage, and then between the same vein and the common carotid artery to the root of the neck. The further course of the nerve differs on the two sides of the body.

On the *right side*, the nerve passes across the first part of the subclavian artery, between it and the right innominate vein, and descends by the side of the trachea to the back of the root of the lung, where it spreads out in the *posterior pulmonary plexus*. From the lower part of this plexus two cords descend on the œsophagus, and divide to form, with branches from the left nerve, the *œsophageal plexus*. Below, these branches are collected into a single cord, which runs along the back of the œsophagus, enters the abdomen, and is distributed to the postero-inferior surface of the stomach, joining the left side of the celiac plexus, and sending filaments to the lienal (splenic) plexus.

On the *left side*, the nerve enters the thorax between the left carotid and subclavian arteries, behind the left innominate vein. It crosses the left side of the arch of the aorta, and descends behind the root of the left lung, forming there the *posterior pulmonary plexus*. From this it runs along the anterior surface of the œsophagus, where it unites with branches of the right nerve in the *œsophageal plexus*, and is continued to the stomach, distributing branches over its anterosuperior surface; some of these extend over the fundus, and others along the lesser curvature. Filaments from these branches enter the lesser omentum, and join the hepatic plexus.

The *jugular ganglion* (ganglion of the root) is of a greyish colour, spherical in form, about 4 mm. in diameter. It is joined by several delicate filaments to the cerebral portion of the accessory nerve; it is connected by a twig with the petrous ganglion of the glossopharyngeal, and with the sympathetic by a filament from the superior cervical ganglion; its auricular branch gives off an ascending branch which joins the facial nerve.

The *ganglion nodosum* (ganglion of the trunk) is cylindrical in form, of a reddish colour, and 2.5 cm. in length. Passing through it is the cerebral portion of the accessory nerve, which blends with the vagus nerve below the ganglion. This ganglion is connected with the hypoglossal nerve, the superior cervical ganglion of the sympathetic trunk, and the loop between the first and second cervical nerves.

The *branches of distribution* of the vagus nerve are :

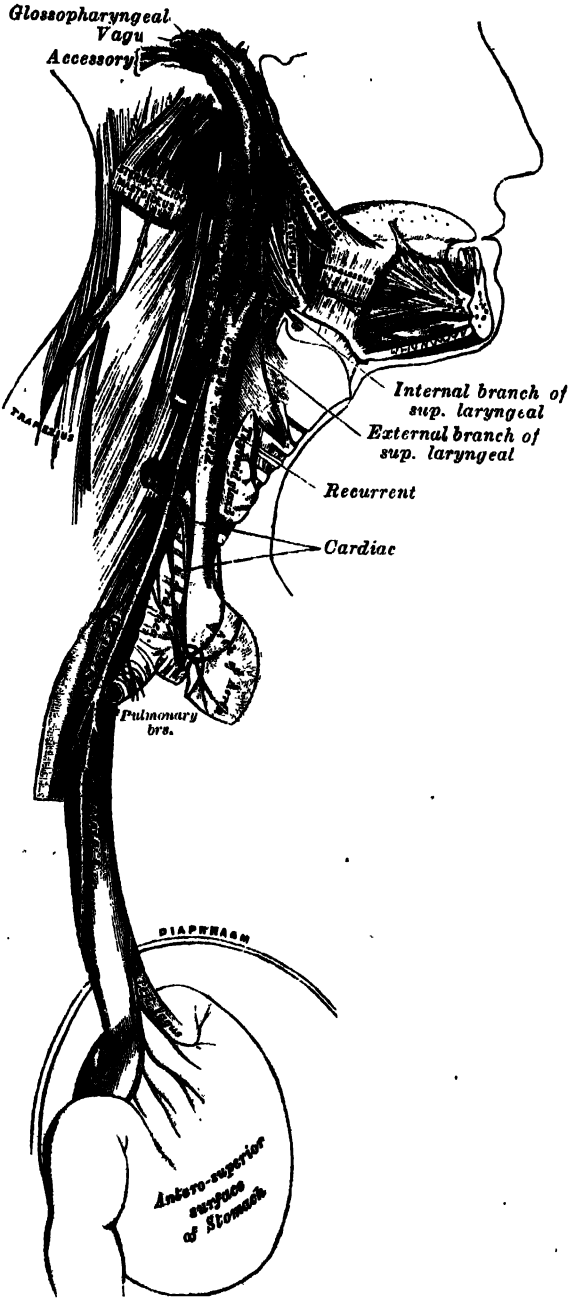
In the jugular fossa	{ Meningeal.
	{ Auricular.
	{ Pharyngeal.
In the neck	{ Superior laryngeal.
	{ Right recurrent.
	{ Superior cardiac.
	{ Inferior cardiac.
In the thorax	{ Left recurrent.
	{ Anterior bronchial.
	{ Posterior bronchial.
	{ Œsophageal.
	{ Gastric.
In the abdomen	{ Celiac.
	{ Hepatic.

The meningeal branch springs from the jugular ganglion of the vagus nerve, and is distributed to the dura mater in the posterior fossa of the skull. The auricular branch (nerve of Arnold) arises from the jugular ganglion of the vagus nerve, and is joined soon after its origin by a filament from the petrous ganglion of the glossopharyngeal; it passes behind the internal jugular vein, and enters the mastoid canaliculus on the lateral wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the facial canal about 4 mm. above the stylomastoid foramen, and here it gives off an ascending branch which joins the facial nerve. It then passes through the tympanomastoid fissure, and divides into two branches; one joins the posterior auricular nerve, the other is distributed to the skin of the back of the auricle and to the posterior part of the external acoustic meatus.

The pharyngeal branch, the principal motor nerve of the pharynx arises from the upper part of the ganglion nodosum of the vagus nerve, and consists principally of filaments from the cerebral portion of the accessory nerve. It passes across the internal carotid artery to the upper border of the Constrictor pharyngis medius, where it divides into numerous filaments which join with branches from the glossopharyngeal, sympathetic, and external laryngeal nerves to form the *pharyngeal plexus*. From the plexus, branches are distributed to the muscles and mucous membrane of the pharynx and the muscles of the soft palate, except the Tensor veli palatini. A minute filament descends and joins the hypoglossal nerve as the latter winds round the occipital artery.

The superior laryngeal nerve, larger than the preceding, arises from the middle of the ganglion nodosum of the vagus nerve and in its course receives

FIG. 828.—The course and distribution of the glossopharyngeal, vagus, and accessory nerves.



The superior laryngeal nerve, larger than the preceding, arises from the middle of the ganglion nodosum of the vagus nerve and in its course receives

a branch from the superior cervical ganglion of the sympathetic. It descends, by the side of the pharynx, behind the internal carotid artery, and divides into two branches, external and internal.

The *external branch*, the smaller, descends on the larynx, beneath the Sternothyroideus, to supply the Cricothyroideus. It gives branches to the pharyngeal plexus and to the Constrictor pharyngis inferior, and, behind the common carotid artery, communicates with the superior cardiac nerve.

The *internal branch* descends to the hyothyroid membrane, pierces it in company with the superior laryngeal artery, and is distributed to the mucous membrane of the larynx. It supplies branches to the epiglottis, the base of the tongue, and the epiglottic glands; others pass backwards, in the ary-epiglottic fold, and are distributed to the mucous membrane around the entrance to the larynx, and to the mucous membrane of the interior of the larynx as low as the vocal folds. A filament descends beneath the mucous membrane on the inner surface of the thyroid cartilage and joins the recurrent nerve.

The recurrent nerve (recurrent laryngeal nerve) differs, as to its origin and course, on the two sides of the body. On the *right* side it arises from the vagus nerve, in front of the first part of the subclavian artery; it winds from before backwards round that vessel, and ascends obliquely to the side of the trachea behind the common carotid artery, and either in front of or behind the inferior thyroid artery. On the *left* side, it arises from the vagus nerve on the left of the arch of the aorta, and winds below the aorta at the point where the ligamentum arteriosum is attached, and then ascends to the side of the trachea. The nerve on either side ascends in the groove between the trachea and œsophagus, passes under the lower border of the Constrictor pharyngis inferior, and enters the larynx behind the articulation of the inferior cornu of the thyroid with the cricoid cartilage; it is distributed to all the muscles of the larynx, excepting the Cricothyroideus. It communicates with the internal branch of the superior laryngeal nerve, and gives off a few filaments to the mucous membrane of the lower part of the larynx.

As the recurrent nerve hooks round the subclavian artery or aorta, it gives off several cardiac filaments to the deep part of the cardiac plexus. As it ascends in the neck it gives off branches, more numerous on the left than on the right side, to the mucous membrane and muscular coat of the œsophagus; branches to the mucous membrane and muscular fibres of the trachea; and some filaments to the Constrictor pharyngis inferior.

The *superior cardiac branches*, two or three in number, arise from the vagus nerve, at the upper and lower parts of the neck.

The *upper branches* are small, and join with the cardiac branches of the sympathetic trunk. They can be traced to the deep part of the cardiac plexus.

The *lower branches* arise at the root of the neck. That from the right vagus passes in front or by the side of the innominate artery, and proceeds to the deep part of the cardiac plexus; that from the left runs down across the left side of the arch of the aorta, and joins the superficial part of the cardiac plexus.

The *inferior cardiac branches*, on the right side, arise from the trunk of the vagus nerve as it lies by the side of the trachea, and from its recurrent nerve; on the left side from the recurrent nerve only. They end in the deep part of the cardiac plexus.

The *anterior bronchial branches*, two or three in number, and of small size, are distributed on the anterior surface of the root of the lung. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus*.

The *posterior bronchial branches*, more numerous and larger than the anterior, are distributed on the posterior surface of the root of the lung; they are joined by filaments from the third and fourth (sometimes also from the first and second) thoracic ganglia of the sympathetic trunk, and form the *posterior pulmonary plexus*. Branches from this plexus accompany the ramifications of the bronchi through the substance of the lung.

The *œsophageal branches* are given off both above and below the bronchial branches; the lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the *œsophageal plexus*. From this plexus filaments are distributed to the œsophagus and to the back of the pericardium.

The **gastric branches** are distributed to the stomach. The right vagus forms the *posterior gastric plexus* on the postero-inferior surface of the stomach, and the left the *anterior gastric plexus* on the anterosuperior surface.

The **cœliac branches** are mainly derived from the right vagus: they join the cœliac plexus and through it supply branches to the pancreas, spleen, kidneys, suprarenal glands, and intestine.

The **hepatic branches** arise from the left vagus: they join the hepatic plexus and through it are conveyed to the liver.

Applied Anatomy.—The trunk of the vagus is rarely injured, but the functions of the nerve may be interfered with by damage to its nucleus of origin in the medulla; by thickening or growth from the meninges or bones, or aneurysm of the basilar artery, before its exit from the skull; injuries such as gunshot or punctured wounds in the neck, or injuries during such operations as ligature of the carotid artery, removal of tuberculous glands or other deep-seated tumours. The vagus may also be compressed by aneurysms of the carotid artery, and its deep origin becomes affected in bulbar paralysis. The symptoms produced by paralysis of the nerve are palpitation, with increased frequency of the pulse, constant vomiting, slowing of the respiration, and a sensation of suffocation.

'Reflexes' on the branches of the vagus are not at all uncommonly met with. The 'ear cough' is perhaps one of the commonest, where a plug of wax in the acoustic meatus may, by irritating the filaments of the auricular (Arnold's) nerve, be responsible for a persistent cough. Syringing the external acoustic meatus frequently produces cough, and, in children, vomiting is not uncommon as the result of such a procedure; moreover, in people with weak hearts, syringing the ear has been responsible for a sudden fatal syncope, by reflex irritation of the cardiac branches. Another very common example is the persistent cough which is frequently due to enlarged bronchial glands in children, the irritation of which is referred to the superior laryngeal filaments.

The anatomy of the laryngeal nerves is of importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of the glottis is the result. When its trunk is pressed upon by, for instance, a goitre or an aneurysm of the upper part of the carotid, there is a peculiar dry, brassy cough. When the nerve is paralysed, there is anaesthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, as the nerve also supplies the Cricothyroideus muscle, the vocal folds cannot be made tense and the voice is deep and hoarse. Paralysis may be the result of bulbar paralysis; may be a sequel to diphtheria, when both nerves are usually involved; or it may, though less commonly, be caused by the pressure of tumours or aneurysms, when the paralysis is generally unilateral. Irritation of the recurrent nerves produces spasm of the muscles of the larynx. When both recurrent nerves are paralysed, the vocal folds are motionless, in the so-called 'cadaveric position'—that is to say, in the position in which they are found in ordinary tranquil respiration; neither closed as in phonation, nor widely open as in deep inspiratory efforts. When one recurrent nerve is paralysed, the vocal fold of the same side is motionless, while the opposite one crosses the middle line to accommodate itself to the affected one; hence phonation is possible, but the voice is altered and weak in timbre. The nerves may be paralysed in bulbar paralysis or after diphtheria, when the paralysis usually affects both sides; or they may be affected by the pressure of aneurysms of the aorta, innominate, or subclavian arteries; by mediastinal tumours; by gunnata; or by cancer of the upper part of the œsophagus, when the paralysis is often unilateral. Paralysis of the adductor muscles of the larynx on both sides is quite common, and is usually functional in nature. The voice is reduced to a whisper, but the power of coughing is preserved.

R.

ACCESSORY NERVE (figs. 826, 827, 828)

The **accessory nerve** (spinal accessory nerve) consists of two parts: a cerebral and a spinal.

The **cerebral part** is the smaller; its fibres arise from the cells of the *nucleus ambiguus* and emerge as four or five delicate rootlets from the side of the medulla oblongata, below the roots of the vagus. It runs lateralwards to the jugular foramen, where it interchanges fibres with the spinal portion or becomes united to it for a short distance; here it is also connected by one or two filaments with the jugular ganglion of the vagus. It passes through the jugular foramen, separates from the spinal portion, and is continued over the ganglion nodosum of the vagus, to the surface of which it is adherent, and is distributed principally to the pharyngeal and superior laryngeal branches of the vagus. Through the pharyngeal branch it probably supplies the *Musculus uvulæ* and *Levator veli palatini*. Some few filaments from it are

continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent nerve and probably also with the cardiac nerve.

The **spinal part** is firm in texture, and its fibres arise from the motor cells in the lateral part of the anterior column of the grey substance of the medulla spinalis as low as the fifth cervical nerve. Passing through the lateral white funiculus of the medulla spinalis, they emerge on its surface and unite to form a **trunk**, which ascends between the ligamentum denticulatum and the posterior roots of the spinal nerves, enters the skull through the foramen magnum, and is then directed to the jugular foramen, through which it passes, lying in the same sheath of dura mater as the vagus nerve, but separated from it by a fold of the arachnoid. In the jugular foramen, it receives one or two filaments from the cerebral part of the accessory nerve, or else joins it for a short distance and then parts from it again. At its exit from the jugular foramen, it runs backwards in front of the internal jugular vein in two-thirds of the cases, and behind it in one-third (Tandler). The nerve then descends obliquely behind the Digastricus and Stylohyoideus to the upper part of the Sternocleidomastoideus; it pierces this muscle, and courses obliquely across the posterior triangle of the neck, to end in the deep surface of the Trapezius. As it traverses the Sternocleidomastoideus it gives several filaments to the muscle, and joins with branches from the second cervical nerve. In the posterior triangle it unites with the second and third cervical nerves, while beneath the Trapezius it forms a plexus with the third and fourth cervical nerves, and from this plexus fibres are distributed to the muscle.

Applied Anatomy.—The functions of the accessory nerve may be interfered with either by central changes; or at its exit from the skull, by fractures running across the jugular foramen; or in the neck, by inflamed lymph-glands, &c. The acute wry-neck in children is most commonly due to inflamed or suppurating glands, and rapidly subsides with appropriate treatment. Central irritation causes clonic spasm of the Sternocleidomastoideus and Trapezius muscles, or, as it is termed, spasmodic torticollis. In cases of this affection in which all previous palliative treatment has failed, and the spasms are so severe as to undermine the patient's health, division or excision of a portion of the accessory nerve has been resorted to. This must be done from the anterior border of the Sternocleidomastoideus. The operation consists in making an incision, 8 cm. in length, from the apex of the mastoid process along the anterior border of the muscle, which is defined and pulled backwards, so as to stretch the nerve, which is then to be sought beneath the Digastricus, about 5 cm. below the apex of the mastoid process. Unfortunately, the operation does not yield a satisfactory or permanent cure, as the spasms tend to recur after an interval, either in the same muscles or in other groups of neck muscles.

In cases where extensive dissections are undertaken for enlarged glands in the neck, it is essential that this nerve should be at once sought and isolated from the mass of inflamed glands so as to maintain its continuity.

HYPGLOSSAL NERVE (figs. 829, 830)

The **hypoglossal nerve** is the motor nerve of the tongue.

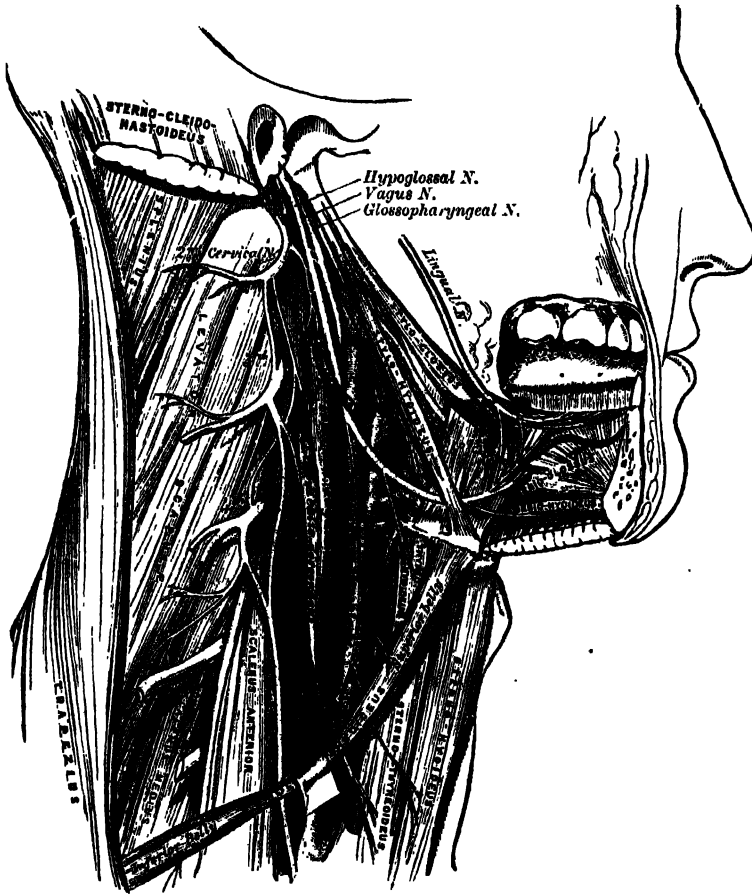
Its fibres arise from the cells of the *hypoglossal nucleus*, which is an upward prolongation of the base of the anterior column of grey substance of the medulla spinalis. This nucleus is about 2 cm. in length, and its upper part corresponds with the *trigonum hypoglossi*, or lower portion of the medial eminence of the rhomboid fossa (p. 786). The lower part of the nucleus extends downwards into the closed part of the medulla oblongata, and there lies in relation to the ventrolateral aspect of the central canal. The fibres run forwards through the medulla oblongata, and emerge in the anterolateral sulcus between the pyramid and the olive.

The rootlets of this nerve are collected into two bundles, which perforate the dura mater separately, opposite the hypoglossal canal in the occipital bone, and unite together after their passage through it; in some cases the canal is divided into two by a small bony spicule. The nerve descends almost vertically to a point corresponding with the angle of the mandible. It is at first deeply seated beneath the internal carotid artery and internal jugular vein, and intimately connected with the vagus nerve; it then passes forwards between the vein and artery, and lower down in the neck becomes superficial below the Digastricus. The nerve then loops round the occipital artery,

and crosses the external carotid and lingual arteries below the tendon of the Digastricus. It passes beneath the tendon of the Digastricus, the Stylohyoideus, and the Mylohyoideus, lying between the last-named muscle and the Hyoglossus, and is then continued forwards in the fibres of the Genioglossus as far as the tip of the tongue, distributing branches to its muscular substance. It communicates with the vagus, sympathetic, first and second cervical, and lingual nerves.

The communications with the vagus nerve take place close to the skull, numerous filaments passing between the hypoglossal nerve and the ganglion

FIG. 829.—The hypoglossal nerve and the cervical plexus.



nodosum of the vagus nerve through the mass of connective tissue which unites the two nerves. As the nerve winds round the occipital artery it gives off a filament to the pharyngeal plexus.

Opposite the atlas the nerve receives branches from the superior cervical ganglion of the sympathetic trunk, and at the same level is joined by a filament from the loop connecting the first and second cervical nerves.

Near the anterior border of the Hyoglossus it is united to the lingual nerve by numerous filaments which ascend upon the muscle.

The branches of distribution of the hypoglossal nerve are :

Meningeal.
Descending.

Thyrohyoid.
Muscular.

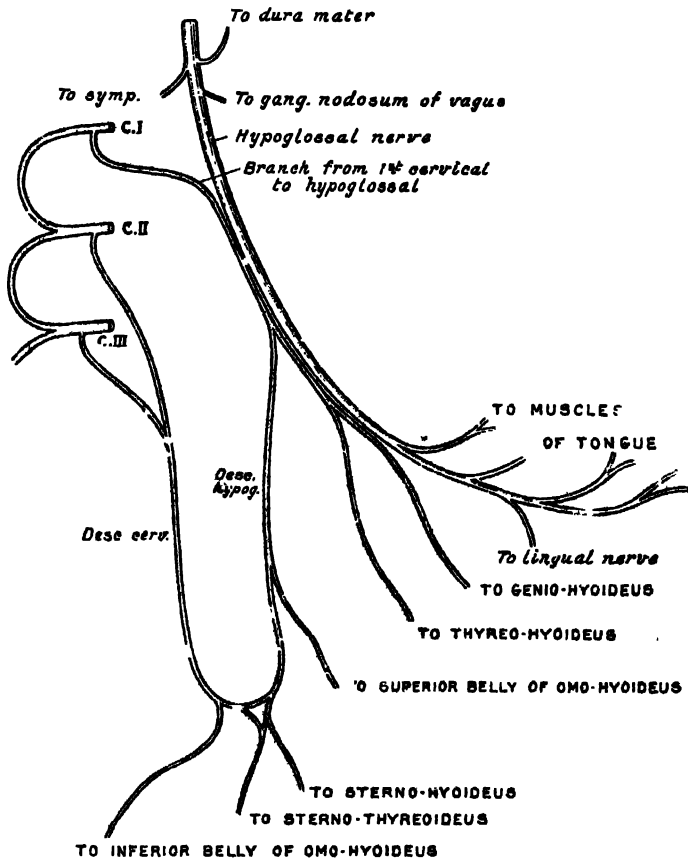
Of these branches the meningeal, descending, thyrohyoid, and the muscular twig to the Geniohyoideus, are probably derived mainly from the branch

which passes from the loop between the first and second cervical to join the hypoglossal (fig. 830).

Meningeal branches.—As the hypoglossal nerve passes through the hypoglossal canal it gives off several filaments to the dura mater in the posterior fossa of the skull.

The **descending ramus**, long and slender, quits the hypoglossal nerve where the latter turns round the occipital artery, and descends in front of or within the sheath of the carotid vessels; it gives a branch to the superior belly of the Omohyoideus, and, just below the middle of the neck, joins the communicantes cervicales from the second and third cervical nerves to form a

FIG. 830.—A plan of the hypoglossal nerve.



loop, the *ansa hypoglossi*. From the convexity of this loop branches pass to supply the Sternohyoideus, the Sternothyreoides, and the inferior belly of the Omohyoideus. According to Arnold, another filament descends in front of the vessels into the thorax, and joins the cardiac and phrenic nerves.

The **thyreohyoid branch** arises from the hypoglossal nerve near the posterior border of the Hyoglossus; it runs obliquely across the greater cornu of the hyoid bone, and supplies the Thyreohyoideus muscle.

The **muscular branches** are distributed to the Styloglossus, Hyoglossus, Geniohyoideus, and Genioglossus. Numerous slender branches pass upwards into the substance of the tongue to supply its intrinsic muscles.

Applied Anatomy.—The hypoglossal nerve is an important guide in the operation of ligature of the lingual artery (p. 582). It runs forwards on the Hyoglossus just above the greater cornu of the hyoid bone, and forms the upper boundary of the triangular space in which the artery is to be sought by cutting through the fibres of the Hyoglossus. In

cases where the nerve is involved by gumma or new growth of the base of the skull, or where it has been injured on one side of the neck, or in some cases of bulbar paralysis, unilateral paralysis, together with hemiatrophy of the tongue, results; the tongue, when protruded, being directed to the paralysed side owing to the unopposed action of the Genioglossus of the opposite side. On retraction, the wasted and paralysed side of the tongue rises up higher than the other. The larynx may deviate towards the sound side on swallowing, from the unilateral paralysis of the depressors of the hyoid bone. If the paralysis is bilateral, e.g. the result of a bullet wound of the infrahyoid region, the tongue lies motionless in the mouth, taste and tactile sensibility of the organ are perfect, articulation is slow and sticky; swallowing is very difficult, and the patient has to throw his head backwards and push the bolus of food back into the pharynx with his finger before he can swallow it.

THE SPINAL NERVES

The **spinal nerves** spring from the medulla spinalis, and are transmitted through the intervertebral foramina. They number thirty-one pairs, which are grouped as follows: Cervical, 8; Thoracic, 12; Lumbar, 5; Sacral, 5; Coccygeal, 1.

The *first cervical nerve* emerges from the vertebral canal between the occipital bone and the atlas, and is therefore called the *suboccipital nerve*; the eighth issues between the seventh cervical and first thoracic vertebrae.

Nerve-roots.—Each nerve is attached to the medulla spinalis by an anterior and a posterior root, the latter being characterised by the presence of a ganglion, the *spinal ganglion*.

The **anterior root** emerges from the anterior surface of the medulla spinalis as a number of rootlets or filaments (*fila radicularia*), which coalesce to form two bundles near the intervertebral foramen.

The **posterior root** (except in the case of the first cervical nerve) is larger than the anterior; its rootlets are attached along the posterolateral furrow of the medulla spinalis and unite to form two bundles which join the spinal ganglion.

The **spinal ganglia** are collections of nerve-cells on the posterior roots of the spinal nerves. Each ganglion is oval in shape, reddish in colour, and its size bears a proportion to that of the nerve-root on which it is situated; it is bifid medially where it is joined by the two bundles of the posterior nerve-root. The ganglia are usually placed in the intervertebral foramina, immediately outside the points where the nerve-roots perforate the dura mater, but there are exceptions to this; thus the ganglia of the first and second cervical nerves lie on the vertebral arches of the atlas and epistropheus respectively, those of the sacral nerves are inside the vertebral canal, while that of the coccygeal nerve is within the sheath of dura mater.

Structure.—The ganglia consist chiefly of unipolar nerve-cells, and from these the fibres of the posterior root take origin; the single process of each cell divides after a short course into a central fibre which enters the medulla spinalis and a peripheral fibre which runs into the spinal nerve (fig. 831). Two other forms of cells are, however, present, viz.: (a) the cells of Dogiel, whose axons ramify close to the cell (type II. of Golgi) and are distributed entirely within the ganglion; and (b) multipolar cells similar to those found in the sympathetic ganglia.

The ganglia of the first pair of cervical nerves may be absent, while small *aberrant ganglia* consisting of groups of nerve-cells are sometimes found on the posterior roots of the upper cervical nerves between the spinal ganglia and the medulla spinalis.

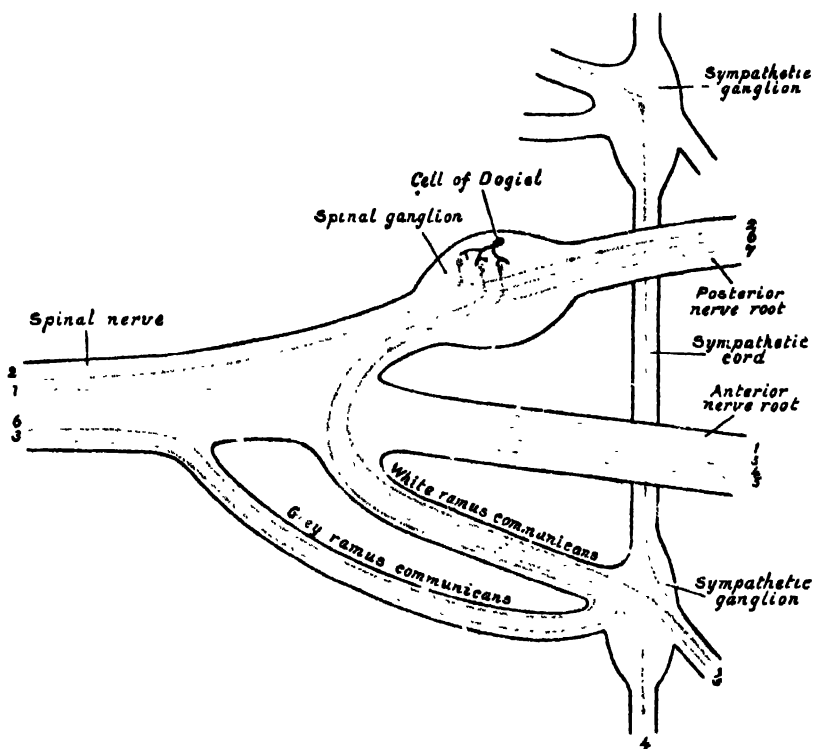
Each nerve-root receives a covering from the pia mater, and is loosely invested by the arachnoid, the latter being prolonged as far as the points where the roots pierce the dura mater. The two roots pierce the dura mater separately, each receiving a sheath from this membrane; where the roots join to form the spinal nerve this sheath is continuous with the epineurium of the nerve.

Size and direction.—The roots of the upper four *cervical* nerves are small, those of the lower four are large. The posterior roots of the cervical nerves bear a proportion to the anterior of three to one, which is greater than in the other regions; their individual filaments are also larger than those of the anterior roots. The posterior root of the first cervical is an exception

to this, being smaller than the anterior root ; in about eight per cent. of cases it is wanting. The roots of the first and second cervical nerves are short, and run nearly horizontally to their points of exit from the vertebral canal. From the third to the eighth cervical they are directed obliquely downwards, the obliquity and length of the roots successively increasing ; the distance, however, between the level of attachment of any of these roots to the medulla spinalis and the points of exit of the corresponding nerves never exceeds the depth of one vertebra.

The roots of the *thoracic* nerves, with the exception of the first, are of small size, and the posterior roots only slightly exceed the anterior in thickness. They increase successively in length, from above downwards, and, in the lower

FIG. 831.—A scheme showing the structure of a typical spinal nerve.



1. Somatic efferent. 2. Somatic afferent. 3, 4, 5. Splanchnic efferent. 6, 7. Splanchnic afferent.

part of the thoracic region, descend in contact with the medulla spinalis for a distance equal to the height of at least two vertebræ before they emerge from the vertebral canal.

The roots of the lower *lumbar* and upper *sacral* nerves are the largest, and their individual filaments the most numerous of all the spinal nerves, while the roots of the *coccygeal* nerve are the smallest.

The roots of the lumbar, sacral, and coccygeal nerves run vertically downwards to their respective exits, and as the medulla spinalis ends near the lower border of the first lumbar vertebra it follows that the length of the successive roots must rapidly increase. As already mentioned (p. 745), the term *cauda equina* is applied to this collection of nerve-roots.

From the description given it will be seen that the largest nerve-roots, and consequently the largest spinal nerves, are attached to the cervical and lumbar swellings of the medulla spinalis ; these nerves are distributed to the upper and lower limbs.

Immediately beyond the spinal ganglion, the anterior and posterior nerve-roots unite to form the *spinal nerve* which emerges through the intervertebral foramen.

Connexions with the sympathetic trunks.—After emerging from the intervertebral foramen each spinal nerve receives a branch (*grey ramus communicans*) from the adjacent ganglion of the sympathetic trunk, while the thoracic and the first and second lumbar nerves each contribute a branch (*white ramus communicans*) to the adjoining sympathetic ganglion. The second, third, and fourth sacral nerves also supply white rami; these, however, are not connected with the ganglia of the sympathetic trunk, but run directly into the pelvic plexuses of the sympathetic.

Structure.—Each typical spinal nerve contains fibres belonging to two systems, viz. the somatic, and the sympathetic or splanchnic, as well as fibres connecting these systems with each other (fig. 831).

1. The **somatic fibres** are efferent and afferent. The *efferent* fibres originate in the cells of the anterior grey column of the medulla spinalis, and run outwards through the anterior nerve-roots to the spinal nerve. They convey impulses to the voluntary muscles, and are continuous from their origin to their peripheral distribution. The *afferent* fibres convey impressions inwards from the skin, &c., and originate in the unipolar nerve-cells of the spinal ganglia. The single processes of these cells divide into peripheral and central fibres, and the latter enter the medulla spinalis through the posterior nerve-roots.

2. The **sympathetic fibres** are also efferent and afferent. The *efferent* or *preganglionic* fibres originate in the lateral column of the medulla spinalis, and are conveyed through the anterior nerve-root and the white ramus communicans to the corresponding ganglion of the sympathetic trunk; here they may end by forming synapses around its cells, or may run through the ganglion to end in another of the ganglia of the sympathetic trunk, or in a more distally placed ganglion in one of the sympathetic plexuses. In all cases they end by forming synapses around other nerve-cells. From the cells of the ganglia of the sympathetic trunk other fibres (*postganglionic*) take origin; some of these run through the grey rami communicantes to join the spinal nerves, while others pass to the viscera, either directly or after interruption in one of the distal ganglia. The *afferent* fibres are derived partly from the unipolar cells and partly from the multipolar cells of the spinal ganglia. Their peripheral processes are carried through the white rami communicantes, and after passing through one or more sympathetic ganglia (but always without interruption in them) finally end in the tissues of the viscera. The central processes of the unipolar cells enter the medulla spinalis through the posterior nerve-root and form synapses around either somatic or sympathetic efferent neurons, thus completing reflex arcs. The dendrites of the multipolar nerve-cells form synapses around the cells of type II. (cells of Dogiel) in the spinal ganglia, and by this path the original impulse is transferred from the sympathetic to the somatic system, through which it is conveyed to the sensorium.

Divisions.—After emerging from the intervertebral foramen, each spinal nerve gives off a small *meningeal branch* which re-enters the vertebral canal through the intervertebral foramen and supplies the vertebrae and their ligaments, and the blood-vessels of the medulla spinalis and its membranes. The spinal nerve then splits into a *posterior* and an *anterior* division, each receiving fibres from both nerve-roots.

POSTERIOR DIVISIONS OF THE SPINAL NERVES

The **posterior divisions** of the spinal nerves are as a rule smaller than the anterior. They are directed backwards, and, with the exceptions of those of the first cervical, the fourth and fifth sacral, and the coccygeal, divide into medial and lateral branches for the supply of the muscles and skin (figs. 832, 833) of the posterior part of the trunk.

POSTERIOR DIVISIONS OF THE CERVICAL NERVES

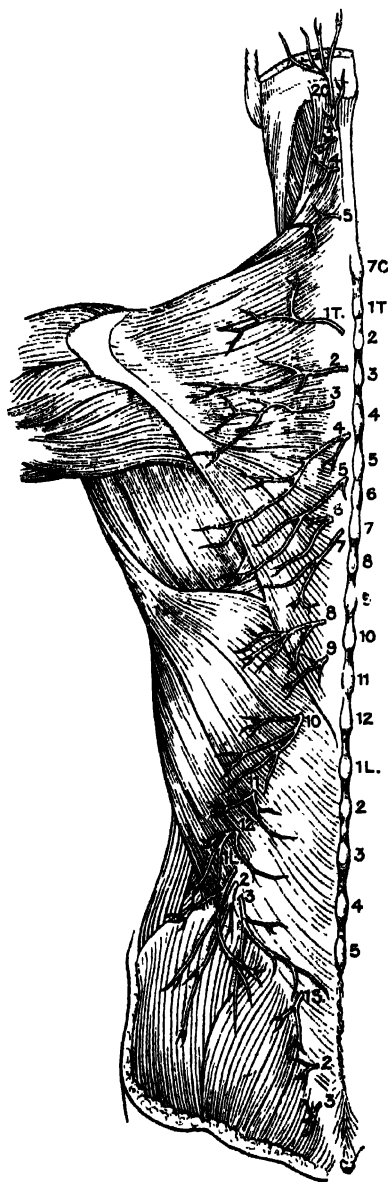
The **posterior division of the first cervical or suboccipital nerve** is larger than the anterior division, and emerges above the posterior arch of the atlas and beneath the vertebral artery. It enters the suboccipital triangle and

supplies the muscles which bound this triangle, viz. the Rectus capitis posterior major, and the Obliqui superior and inferior; it gives branches also to the Rectus capitis posterior minor and the Semispinalis capitis. A filament from the branch to the Obliquus inferior joins the posterior division of the second cervical nerve.

The nerve occasionally gives off a cutaneous branch which accompanies the occipital artery to the scalp, and communicates with the greater and lesser occipital nerves.

The posterior division of the second cervical nerve is much larger

FIG. 832.—A diagram of the distribution of the cutaneous branches of the posterior divisions of the spinal nerves.



than the anterior division, and is the greatest of all the cervical posterior divisions. It emerges between the posterior arch of the atlas and the lamina of the epistropheus, below the Obliquus inferior. It supplies a twig to this muscle, receives a communicating filament from the posterior division of the first cervical, and then divides into a large medial and a small lateral branch.

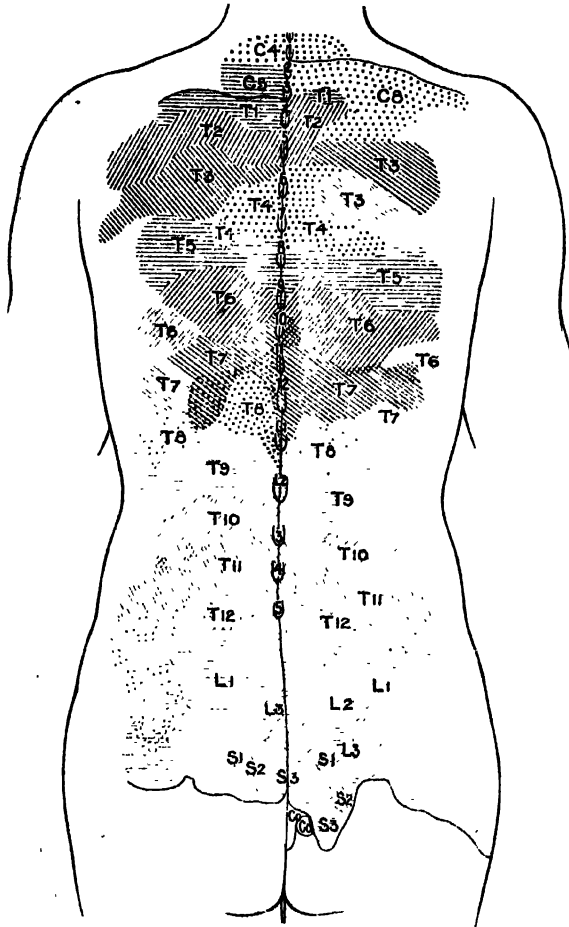
The *medial* branch, called from its size and distribution, the *greater occipital nerve*, ascends obliquely between the Obliquus inferior and the Semispinalis capitis, and pierces the latter muscle and the Trapezius near their attachments to the occipital bone (fig. 832). It is then joined by a filament from the medial branch of the posterior division of the third cervical, and, ascending on the back of the head with the occipital artery, divides into branches which communicate with the lesser occipital nerve and supply the skin of the scalp as far forward as the vertex of the skull. It gives off muscular branches to the Semispinalis capitis, and occasionally a twig to the back of the auricula. The *lateral* branch supplies filaments to the Splenius, Longus capitis, and Semispinalis capitis, and is often joined by the corresponding branch of the third cervical.

The posterior division of the third cervical is intermediate in size between those of the second and fourth. Its *medial* branch runs between the Semispinalis capitis and Semispinalis cervicis, and, piercing the Splenius and Trapezius, ends in the skin. While under the Trapezius it gives off a branch called the *third occipital nerve*, which pierces the Trapezius and ends in the skin of the lower part of the back of the head (fig. 832). It lies medially to, and communicates with, the greater occipital nerve. The *lateral* branch often joins that of the second cervical.

The posterior division of the suboccipital, and the medial branches of the posterior divisions of the second and third cervical nerves are sometimes joined by communicating loops to form, the *posterior cervical plexus* (Orrueilhier).

The posterior divisions of the lower five cervical nerves divide into medial and lateral branches. The *medial* branches of the fourth and fifth run between the Semispinalis cervicis and Semispinalis capitis, and, having reached the spinous processes, pierce the Splenius and Trapezius to end in the skin (fig. 832). Sometimes the medial branch of the fifth fails to reach the

FIG. 888.—The areas of distribution of the cutaneous branches of the posterior divisions of the spinal nerves. (H. M. Johnston.)



The areas of the medial branches are in black, those of the lateral in red.

skin. The medial branches of the lowest three nerves are small, and end in the Semispinalis cervicis, Semispinalis capitis, Multifidus and Interspinales. The *lateral* branches of the lower five nerves supply the Iliocostalis cervicis, Longissimus cervicis, and Longissimus capitis.

POSTERIOR DIVISIONS OF THORACIC NERVES

The *medial* branches of the posterior divisions of the upper six thoracic nerves run between the Semispinalis dorsi and Multifidus, which they supply; they then pierce the Rhomboidei and Trapezius, and reach the skin by the sides of the spinous processes (fig. 832). The medial branches of the lower six are distributed chiefly to the Multifidus and Longissimus dorsi; occasionally they give filaments to the skin near the middle line.

The *lateral* branches increase in size from above downwards. They run through or beneath the Longissimus dorsi to the interval between it and the Iliocostalis, and supply these muscles; the lower five or six also give off cutaneous branches which pierce the Serratus posterior inferior and Latissimus dorsi in a line with the angles of the ribs (fig. 832). The lateral branches of a variable number of the upper thoracic nerves also give filaments to the skin. The lateral branch of the twelfth thoracic, after sending a filament medialwards along the iliac crest, passes downwards to the skin of the anterior part of the buttock.

The medial cutaneous branches of the posterior divisions of the thoracic nerves descend for some distance close to the spinous processes before reaching the skin, while the lateral branches travel downwards for a considerable distance—it may be as much as the breadth of four ribs—before they become superficial; the branch from the twelfth thoracic, for instance, reaches the skin only a little way above the iliac crest.*

POSTERIOR DIVISIONS OF LUMBAR NERVES

The *medial* branches of the posterior divisions of the lumbar nerves run close to the articular processes of the vertebræ and end in the Multifidus.

The *lateral* branches supply the Sacrospinalis. The upper three give off cutaneous nerves which pierce the aponeurosis of the Latissimus dorsi at the lateral border of the Sacrospinalis and cross the posterior part of the iliac crest to the skin of the buttock (fig. 832), some of their twigs running as far as the level of the greater trochanter.

POSTERIOR DIVISIONS OF SACRAL NERVES

The posterior divisions of the sacral nerves are small, and diminish in size from above downwards; they emerge, except the last, through the posterior sacral foramina. The *upper three* are covered at their points of exit by the Multifidus, and divide into medial and lateral branches.

The *medial* branches are small, and end in the Multifidus.

The *lateral* branches join with one another and with the lateral branches of the posterior divisions of the last lumbar and fourth sacral to form loops on the dorsal surface of the sacrum. From these loops branches run to the dorsal surface of the sacrotuberous ligament and form a second series of loops under the Glutæus maximus. From this second series of loops cutaneous nerves (nn. clunium medii), two or three in number, pierce the Glutæus maximus along a line drawn from the posterior superior iliac spine to the tip of the coccyx; they supply the skin over the posterior part of the buttock.

The posterior divisions of the *lower two* sacral nerves are small and lie below the Multifidus. They do not divide into medial and lateral branches, but unite with each other and with the posterior division of the coccygeal nerve to form loops on the back of the sacrum; filaments from these loops supply the skin over the coccyx.

POSTERIOR DIVISION OF COCCYGEAL NERVE

The posterior division of the coccygeal nerve does not divide into a medial and a lateral branch, but receives, as already stated, a communicating branch from the last sacral; it is distributed to the skin over the back of the coccyx.

ANTERIOR DIVISIONS OF THE SPINAL NERVES

The anterior divisions of the spinal nerves supply the anterolateral parts of the trunk, and the limbs; they are for the most part larger than the posterior divisions. In the thoracic region they run independently of one another, but in the cervical, lumbar, and sacral regions they unite near their origins to form plexuses.

* H. M. Johnston, *Journal of Anatomy and Physiology*, vol. xliii.

ANTERIOR DIVISIONS OF CERVICAL NERVES

The anterior divisions of the cervical nerves, with the exception of the first, appear between the corresponding anterior and posterior inter-transverse muscles. The anterior divisions of the *upper four* nerves unite to form the *cervical plexus*; those of the *lower four*, together with the greater part of the anterior division of the first thoracic nerve, join to form the *brachial plexus*.

Each nerve receives a grey ramus communicans, the upper four from the superior cervical ganglion, the fifth and sixth from the middle cervical ganglion, and the seventh and eighth from the inferior cervical ganglion, of the sympathetic trunk.

The anterior division of the *first cervical (suboccipital) nerve* appears above the posterior arch of the atlas vertebra, and passes forwards round the lateral side of its superior articular process, medially to the vertebral artery. It supplies a branch to the Rectus lateralis muscle, and, emerging on the medial side of that muscle, descends in front of the transverse process of the atlas and joins with the ascending branch of the second nerve.

The anterior division of the *second cervical nerve* issues between the neural arches of the atlas and epistropheus and runs forwards between the transverse processes of these two vertebrae, passing under cover of the first posterior intertransverse muscle and on the lateral side of the vertebral artery. It divides into an ascending branch which joins with the first cervical nerve, and a descending branch which unites with the ascending branch of the third cervical nerve.

CERVICAL PLEXUS

The *cervical plexus* (fig. 834) is formed by the anterior divisions of the upper four cervical nerves; each nerve, except the first, divides into an upper and a lower branch, and these unite to form three loops. The plexus is situated opposite the upper four cervical vertebrae, in front of the Levator scapulae and Scalenus medius, and beneath the Sternocleidomastoideus.

Its branches are divided into two groups, *superficial* and *deep*, and are here given in tabular form; the figures following the names indicate the spinal nerves from which the different branches take origin:

		<i>Superficial</i>		Smaller occipital	2 C.
				Great auricular	2, 3 C.
				Cutaneous cervical	2, 3 C.
				Supraclavicular	3, 4 C.
<i>Deep</i>	<i>Medial</i>	<i>Communicating</i>	{	With hypoglossal	1, 2 C.
				„ vagus	1, 2 C.
				„ sympathetic	1, 2, 3, 4 C.
				Rectus capitis lateralis	1 C.
				Rectus capitis anterior	1, 2 C.
	<i>Muscular</i>	{		Longus capitis	1, 2, 3 C.
				Communicantes cervicales	2, 3 C.
				Phrenic	3, 4, 5 C.
				Communicating with accessory	2, 3, 4 C.
				Sternocleidomastoideus	2 C.
<i>Lateral</i>	<i>Muscular</i>	{		Trapezius	3, 4 C.
				Levator scapulae	3, 4 C.
				Scalenus medius	3, 4 C.

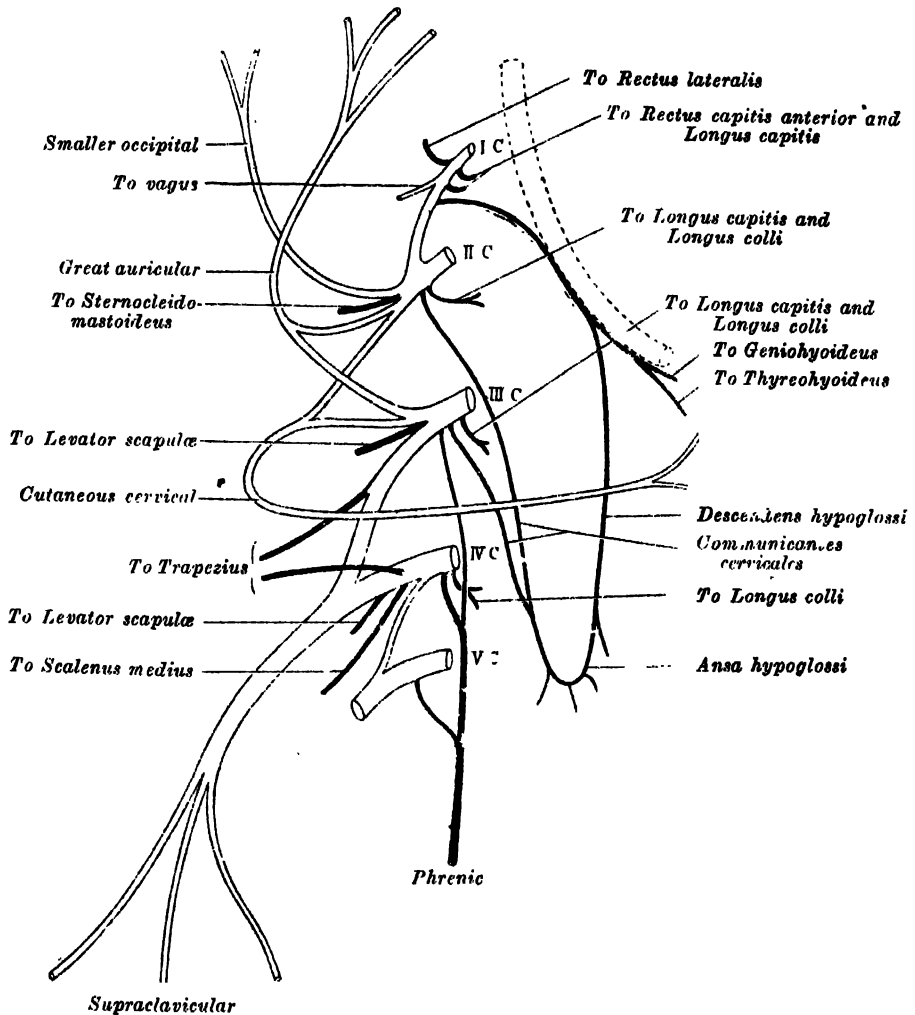
SUPERFICIAL BRANCHES OF THE CERVICAL PLEXUS (fig. 835)

The *smaller occipital nerve* arises from the second cervical nerve, sometimes also from the third; it hooks round the accessory nerve and ascends along the posterior border of the Sternocleidomastoideus. Near the cranium it perforates the deep fascia, and is continued upwards along the side of the head behind the auricula, supplying the skin and communicating with the great

auricular and greater occipital nerves, and with the posterior auricular branch of the facial nerve. The smaller occipital nerve varies in size, and is sometimes duplicated.

It gives off an *auricular branch* which supplies the skin of the upper third of the cranial surface of the auricula, and communicates with the mastoid branch of the great auricular nerve. The auricular branch is occasionally derived from the greater occipital nerve.

FIG. 894.—A plan of the cervical plexus.



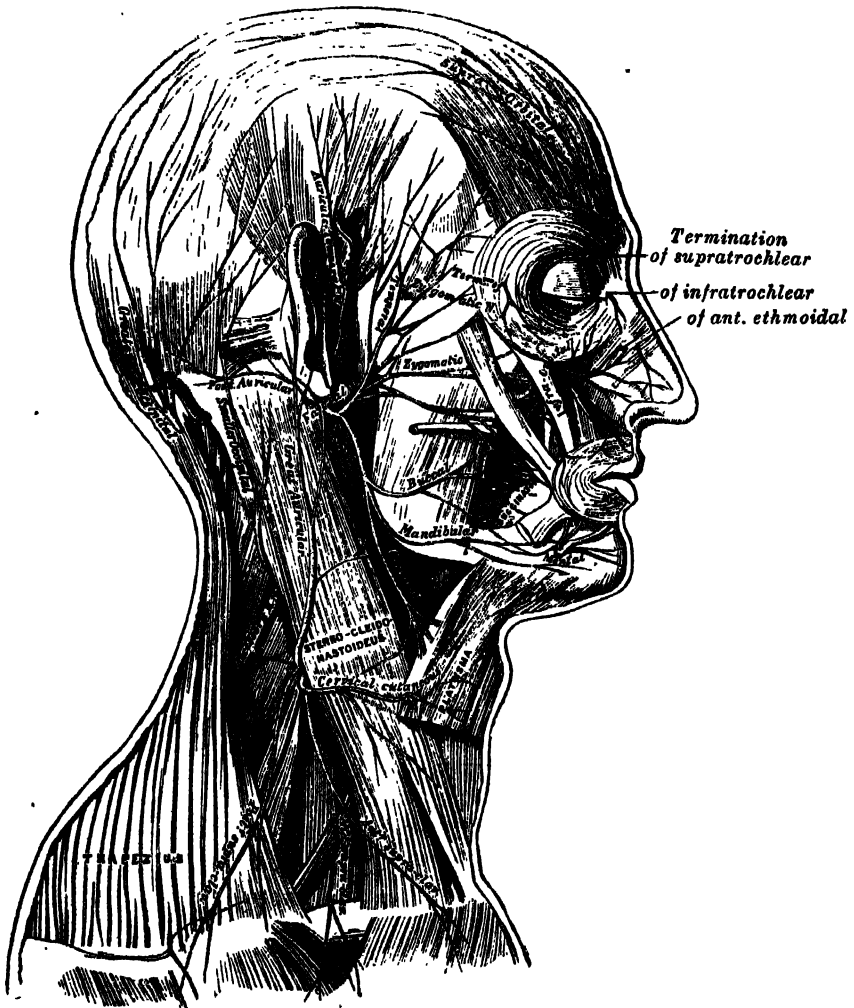
The great auricular nerve is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sternocleidomastoideus, and, after perforating the deep fascia ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into an anterior and a posterior branch.

The *anterior branch* is distributed to the skin of the face over the parotid gland, and communicates in the substance of the gland with the facial nerve.

The *posterior branch* supplies the skin over the mastoid process and on the back of the auricula, except at its upper part; a filament pierces the auricula to reach its lateral surface, where it is distributed to the lobule and lower part of the concha. The posterior branch communicates with the smaller occipital nerve, the auricular branch of the vagus nerve, and the posterior auricular branch of the facial nerve.

The cutaneous cervical nerve (transverse cervical nerve) arises from the second and third cervical nerves, turns round the posterior border of the Sternocleidomastoideus about its middle, and passes obliquely forwards behind the external jugular vein to the anterior border of the muscle. It perforates the deep cervical fascia, and divides beneath the Platysma into ascending and descending branches, which are distributed to the anterolateral parts of the neck.

FIG. 835.—The nerves of the scalp, face, and side of neck.



The *ascending branches* pass upwards to the submaxillary region, and form a plexus with the cervical branch of the facial nerve beneath the Platysma; others pierce that muscle, and are distributed to the skin of the upper and front parts of the neck.

The *descending branches* pierce the Platysma, and are distributed to the skin of the side and front of the neck, as low as the sternum.

The *supraclavicular nerves* arise by a common trunk derived from the third and fourth cervical nerves. This trunk emerges from beneath the posterior border of the Sternocleidomastoideus, descends under cover of the Platysma, and deep cervical fascia, and subdivides into anterior, middle, and posterior branches which diverge from one another and pierce the deep fascia a little above the level of the clavicle.

The *anterior supraclavicular nerves* cross obliquely over the external jugular vein and the clavicular and sternal heads of the Sternocleidomastoideus, and

supply the skin as far as the middle line. They furnish one or two filaments to the sternoclavicular joint.

The *middle supraclavicular nerves* cross the clavicle, and supply the skin over the Pectoralis major and Deltoideus, communicating with the cutaneous branches of the upper intercostal nerves.

The *posterior supraclavicular nerves* pass obliquely across the outer surface of the Trapezias and the acromion, and supply the skin of the upper and posterior parts of the shoulder.

DEEP BRANCHES OF THE CERVICAL PLEXUS. MEDIAL SERIES

The *communicating branches* consist of several filaments, which pass from the loop between the first and second cervical nerves to the vagus, hypoglossal, and sympathetic. The branch to the hypoglossal ultimately leaves that nerve as a series of branches, viz. the descending ramus, the nerve to the Thyrohyoideus and the nerve to the Geniohyoideus (p. 884). A communicating branch also passes from the fourth to the fifth cervical nerve, while each of the first four cervical nerves receives a grey ramus communicans from the superior cervical ganglion of the sympathetic.

Muscular branches supply the Longus capitis, Rectus capitis anterior, and Rectus capitis lateralis.

The *communicantes cervicales* (fig. 834) consist usually of two branches, one derived from the second, and the other from the third cervical nerve. These branches join to form the *descendens cervicalis*, which passes downwards on the lateral side of the internal jugular vein, crosses in front of the vein a little below the middle of the neck, and forms a loop (*ansa hypoglossi*) with the descending ramus of the hypoglossal in front of the sheath of the carotid vessels (p. 877). Occasionally, the loop is formed within the sheath.

The *phrenic nerve* contains motor and sensory fibres in the proportion of about two to one. It arises chiefly from the fourth cervical nerve, but receives a branch from the third and another from the fifth; the fibres from the fifth occasionally come through the nerve to the Subclavius. It is formed at the lateral border of the Scalenus anterior, and descends to the root of the neck, running obliquely across the front of that muscle, and beneath the Sternocleidomastoideus, the inferior belly of the Omohyoideus, and the transverse cervical and transverse scapular vessels. It next passes in front of the subclavian artery, between it and the subclavian vein, and, as it enters the thorax, crosses the internal mammary artery near its origin. Within the thorax, it descends nearly vertically in front of the root of the lung, and then between the pericardium and the mediastinal pleura, to the Diaphragm, where it divides into branches which pierce that muscle, and are distributed to its under surface. In the thorax it is accompanied by the pericardiophrenic branch of the internal mammary artery.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The *right nerve* is situated more deeply, and is shorter and more vertical in direction than the left. It descends in front of the Scalenus anterior which separates it from the second part of the subclavian artery. It lies laterally to the right innominate vein and superior vena cava.

The *left nerve* is rather longer than the right, from the inclination of the heart to the left side, and from the Diaphragm being lower on this than on the right side. At the root of the neck it crosses the first part of the subclavian artery, and is crossed by the thoracic duct. In the superior mediastinal cavity it lies between the left common carotid and left subclavian arteries, and crosses superficially to the vagus on the left side of the arch of the aorta.

Each nerve supplies branches to the pericardium and pleura, and at the root of the neck is joined by a filament from the sympathetic, and, occasionally, by one from the ansa hypoglossi. Branches have been described as passing to the peritoneum.

From the *right nerve*, one or two filaments pass to join in a small *phrenic ganglion* with phrenic branches of the coeliac plexus; and branches from this ganglion are distributed to the falciform and coronary ligaments of the liver, the suprarenal gland, and inferior vena cava. From the *left nerve*, filaments

pass to join the phrenic branches of the coeliac plexus, but without any ganglionic enlargement; and a twig is distributed to the left suprarenal gland.

Applied Anatomy.—In addition to its supply from the phrenics, the Diaphragm receives both motor and sensory nerve-fibres from the lower seven intercostal nerves at its rim. This double sensory innervation explains the varied distribution of the referred pains that may be felt in different cases of infection or inflammation of the Diaphragm, such as may occur in pleurisy or pneumonia affecting its upper surface, on the one hand, or in peritonitis attacking its lower surface on the other. For example, if it is the more central part of the Diaphragm that becomes inflamed in a case of acute peritonitis, the patient may complain of pain and tenderness in the area of distribution of the cutaneous branches of the fourth and fifth cervical nerves, with the result that disease of the shoulder-joint or supraclavicular region is erroneously suspected, and the peritonitis is missed. Contrariwise, if the periphery of the Diaphragm chances to become infected in a patient with acute pleurisy or pneumonia, he may complain of acute pain and tenderness in the area of distribution of the cutaneous branches of the lower intercostal nerves, and may also exhibit rigidity of the underlying abdominal muscles, with the result that an acute intra-abdominal infection is erroneously diagnosed and a laparotomy is performed for the relief of a supposed appendicitis, cholecystitis, or localised peritonitis.

DEEP BRANCHES OF THE CERVICAL PLEXUS. LATERAL SERIES

Communicating branches.—The lateral series of deep branches of the cervical plexus communicates with the accessory nerve, in the substance of the Sternocleidomastoideus, in the posterior triangle, and beneath the Trapezius.

Muscular branches are distributed to the Sternocleidomastoideus, Trapezius, Levator scapulæ, and Scalenus medius.

The branch for the Sternocleidomastoideus is derived from the second cervical nerve; the Trapezius and Levator scapulæ receive branches from the third and fourth cervical nerves. The Scalenus medius receives twigs either from the third or fourth cervical nerves, or occasionally from both.

Applied Anatomy.—Pains referred to the terminal branches of the cervical plexus are not uncommon in cases of the cervical vertebrae, where pain may be felt radiating over the occipital bone, if the disease is situated high up in the vertebral column.

THE BRACHIAL PLEXUS

The brachial plexus (fig. 836) is formed by the union of the anterior divisions of the lower four cervical nerves and the greater part of the anterior division of the first thoracic nerve; the fourth cervical nerve usually gives a branch to the fifth cervical, and the first thoracic nerve frequently receives one from the second thoracic. The plexus extends from the lower part of the side of the neck to the axilla. The nerves which form it are nearly equal in size, but their mode of communication is subject to some variation. The following is, however, the most constant arrangement. The fifth and sixth cervical nerves unite at the lateral border of the Scalenus medius to form a trunk. The eighth cervical and first thoracic nerves unite behind the Scalenus anterior to form a trunk, while the seventh cervical nerve runs alone. Three trunks—upper, middle, and lower—are thus formed, and, as they pass beneath the clavicle, each splits into an *anterior* and a *posterior* division.* The anterior divisions of the upper and middle trunks unite to form a cord, which is situated on the lateral side of the second part of the axillary artery, and is called the *lateral cord or fasciculus* of the plexus. The anterior division of the lower trunk passes down on the medial side of the axillary artery, and forms the *medial cord or fasciculus* of the brachial plexus. The posterior divisions of all three trunks unite to form the *posterior cord or fasciculus* of the plexus, which is situated behind the second portion of the axillary artery.

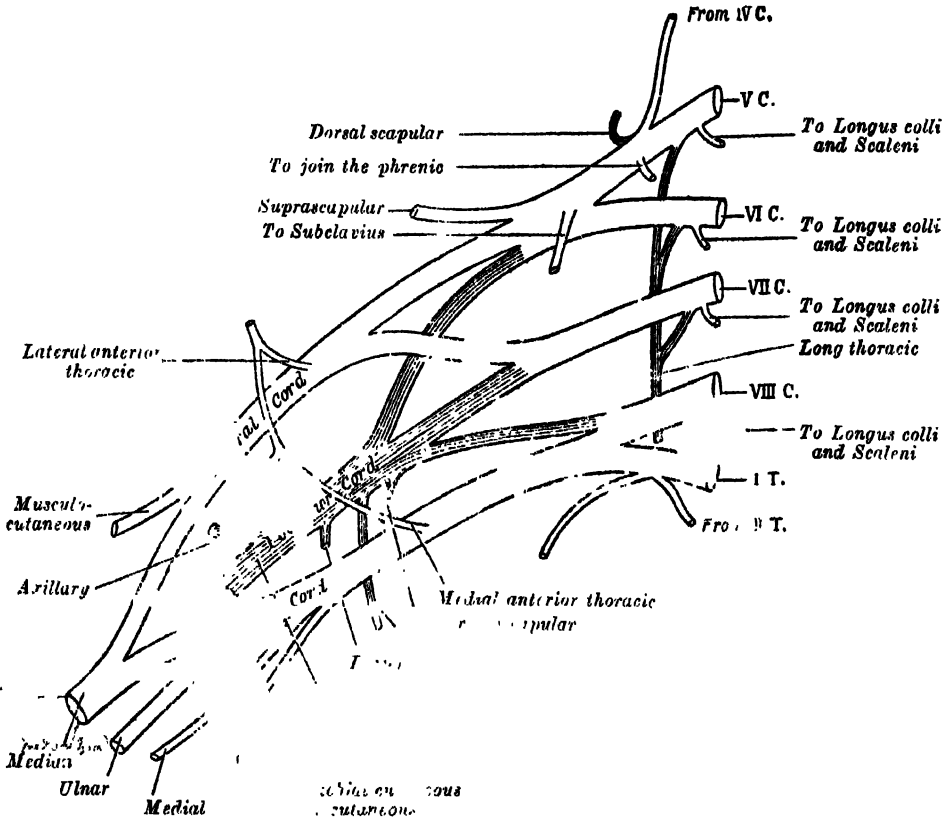
Relations.—*In the neck*, the brachial plexus lies in the posterior triangle, being covered by the skin, Platysma, and deep fascia; it is crossed by the supraclavicular nerves, the nerve to the Subclavius, the inferior belly of the Omohyoideus, the external jugular vein, and the transverse cervical artery. It emerges between the Scalenus anterior and Scalenus medius; its upper part lies above the third part of the subclavian artery, while the trunk formed by

* The posterior division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve.

the union of the eighth cervical and first thoracic nerves is placed behind the artery; the plexus next passes behind the clavicle, the Subclavius, and the transverse scapular vessels, and lies upon the first digitation of the Serratus anterior, and the Subscapularis. In the axilla it is placed laterally to the first portion of the axillary artery; it surrounds the second part of the artery, one cord lying medially to it, one laterally to it, and one behind it; at the lower part of the axilla it gives off its terminal branches to the upper limb.

Close to their exit from the intervertebral foramina the fifth and sixth cervical nerves each receive a grey ramus commensurate with the middle cervical ganglion, and the seventh and eighth cervical similar twigs from the inferior

FIG. 836.—A plan of the brachial plexus.



cervical ganglion, and the sympathetic trunk. The first thoracic nerve receives a grey ramus from, and the first thoracic ganglion receives a white ramus to, the first thoracic ganglion of the sympathetic trunk.

Branches of the brachial plexus.—The branches of the brachial plexus may be arranged in two groups, viz. those given off above the clavicle (*supraclavicular*) and those given off below that bone (*infraclavicular*).

SUPRACLAVICULAR BRANCHES

To phrenic nerve	5 C.
Dorsal scapular	5 C.
Suprascapular	5, 6 C.
Nerve to Subclavius	5, 6 C.
Long thoracic	5, 6, 7 C.
To Longus colli and Scaleni	5, 6, 7 C.

On the Scalenus anterior the phrenic nerve is joined by a branch from the fifth cervical nerve.

The **dorsal scapular nerve** arises from the fifth cervical nerve, pierces the *Scalenus medius*, passes beneath the *Levator scapulæ*, to which it occasionally gives a twig, and runs in company with the descending branch of the **transverse scapular artery** on the anterior surface of the *Rhomboidei*: it ends by supplying these muscles.

The **suprascapular nerve** (fig. 842) is a large nerve which arises from the trunk formed by the union of the fifth and sixth cervical nerves. It runs lateralwards beneath the *Trapezius* and the *Omohyoideus*, and enters the *supraspinatous fossa* through the *suprascapular notch*, below the *superior transverse scapular ligament*; it then passes beneath the *Supraspinatus*, and curves round the lateral border of the spine of the scapula to the *infraspinatous fossa* in company with the *transverse scapular artery*. In the *supraspinatous fossa* it gives off two branches to the *Supraspinatus* muscle, and articular filaments to the shoulder-joint and the *acromioclavicular joint*; and in the *infraspinatous fossa* it gives off two branches to the *Infraspinatus* muscle, besides some filaments to the shoulder-joint and scapula.

The **nerve to the Subclavius** is a small nerve which arises from the point of junction of the fifth and sixth cervical nerves; it descends to the muscle in front of the third part of the *subclavian artery* and the lower trunk of the plexus, and is usually connected by a filament with the *phrenic nerve*.

The **long thoracic nerve** (nerve of Bell) (fig. 841) supplies the *Serratus anterior*. It usually arises by three roots from the fifth, sixth, and seventh cervical nerves, but the root from the seventh nerve may be absent. The roots from the fifth and sixth nerves pierce the *Scalenus medius*, while that from the seventh passes lateralwards in front of the muscle. The nerve descends behind the *brachial plexus* and the first part of the *axillary vessels*, resting on the outer surface of the *Serratus anterior*. It extends along the side of the thorax to the lower border of that muscle, supplying filaments to each of its digitations.

The branches for the *Longus colli* and *Scaleni* arise from the lower four cervical nerves close to their points of exit from the *intervertebral foramina*.

INFRACLAVICULAR BRANCHES

The *infraclavicular branches* are derived from the three cords of the *brachial plexus*, but their fibres may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

Lateral cord	Lateral anterior thoracic	5, 6, 7 C.
	Musculocutaneous	5, 6, 7 C.
	Lateral head of median	6, 7 C.
Medial cord	Medial anterior thoracic	
	Medial antibrachial cutaneous	
	Medial brachial cutaneous	8 C., 1 T.
	Ulnar	
	Medial head of median	
Posterior cord	Upper subscapular	5, 6 C.
	Lower subscapular	5, 6 C.
	Thoracodorsal	5, 6, 7 C.
	Axillary	5, 6 C.
	Radial	6, 7, 8 C., 1 T.

The **anterior thoracic nerves** (fig. 841) supply the *Pectoralis major* and *Pectoralis minor*.

The *lateral anterior thoracic nerve*, the larger of the two, arises, immediately below the clavicle, from the lateral cord of the *brachial plexus*, and through it from the fifth, sixth, and seventh cervical nerves. It crosses the *axillary artery* and vein, pierces the *coracoclavicular fascia*, and is distributed to the deep surface of the *Pectoralis major*. It sends a filament to join the *medial anterior thoracic* and form with it a loop in front of the first part of the *axillary artery*.

The *medial anterior thoracic nerve* receives its fibres from the eighth cervical and first thoracic nerves, and arises from the medial cord of the plexus while that cord is still on the lateral side of the *axillary artery*. It passes behind the first part of the *axillary artery*, curves forwards between the *axillary*

NEUROLOGY

artery and vein, and unites in front of the artery with a filament from the lateral anterior thoracic nerve. It then enters the deep surface of the Pectoralis minor and supplies that muscle. Two or three branches pierce the Pectoralis minor and end in the Pectoralis major.

FIG. 887.—The cutaneous nerves of the right upper extremity. Anterior

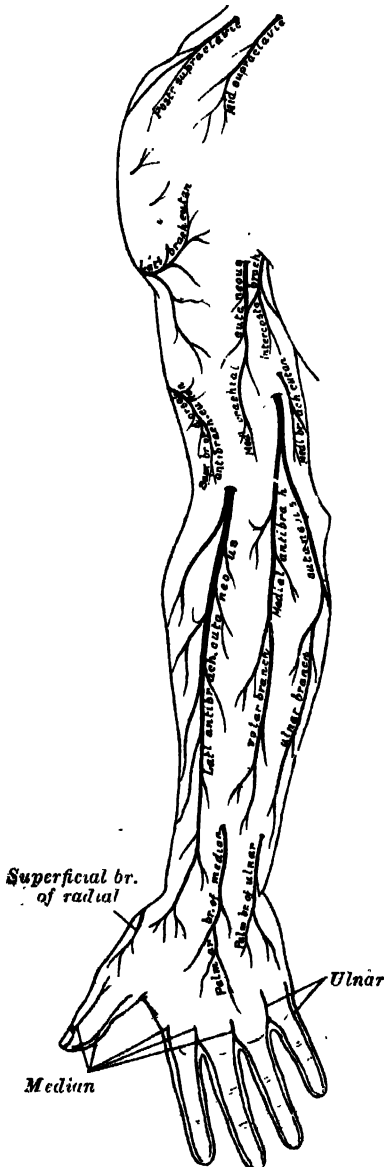
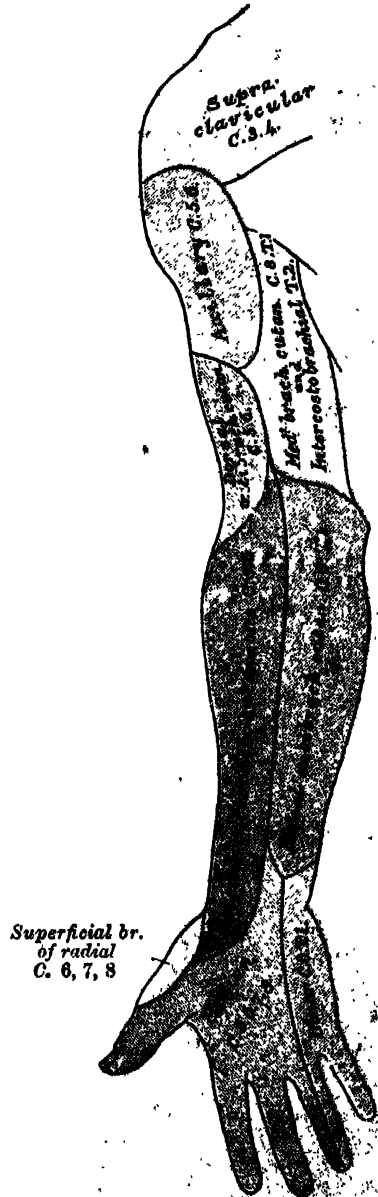


FIG. 888.—A diagram of the segmental distribution of the cutaneous nerves of the right upper extremity. Anterior view.



The subscapular nerves, two in number, spring from the posterior cord of the plexus, and through it from the fifth and sixth cervical nerves.

The *upper subscapular* nerve, the smaller, enters the upper part of the Subscapularis, and is frequently represented by two branches.

The *lower subscapular* nerve supplies the lower part of the Subscapularis, and ends in the *Teres major*; the latter muscle is sometimes supplied by a separate branch.

BRACHIAL PLEXUS

The *thoracodorsal nerve* (long subscapular nerve), a branch of the posterior cord of the plexus, derives its fibres from the fifth, sixth, and seventh cervical nerves; it follows the course of the subscapular artery, along the posterior wall of the axilla to supply the *Latissimus dorsi*, in which it may be traced as far as the lower border of the muscle.

The *axillary nerve* (circumflex nerve) (fig. 842) arises from the posterior cord of the brachial plexus, and its fibres are derived from the fifth and sixth cervical nerves. It lies at first behind the axillary artery and in front of the *Subscapularis*, and passes downwards to the lower border of that muscle. It then winds backwards, in company with the posterior humeral circumflex artery, through a quadrilateral space bounded above by the *Subscapularis* in front and the *Teres minor* behind, below by the *Teres major*, medially by the long head of the *Triceps brachii*, and laterally by the surgical neck of the humerus, and divides into an anterior and a posterior branch.

The *anterior branch* winds round the surgical neck of the humerus, beneath the *Deltoides*, with the posterior humeral circumflex vessels, as far as the anterior border of the muscle, supplying it, and giving a few small cutaneous branches, which pierce the muscle and ramify in the skin covering its lower part.

The *posterior branch* supplies the *Teres minor* and the posterior part of the *Deltoides*; upon the branch to the *Teres minor* an oval enlargement (pseudo-ganglion) usually exists. The posterior branch then pierces the deep fascia and is continued as the *lateral brachial cutaneous nerve*, which sweeps round the posterior border of the *Deltoides* and supplies the skin over the lower two-thirds of the posterior part of this muscle, as well as that covering the long head of the *Triceps brachii* (figs. 837, 839).

The trunk of the axillary nerve gives off an articular filament which enters the shoulder-joint below the *Subscapularis*.

The *musculocutaneous nerve* (fig. 841) arises from the lateral cord of the brachial plexus, opposite the lower border of the *Pectoralis minor*, its fibres being derived from the fifth, sixth, and seventh cervical nerves. It pierces the *Coracobrachialis* muscle and passes obliquely between the *Biceps brachii* and the *Brachialis*, to the lateral side of the arm; a little below the elbow it pierces the deep fascia laterally to the tendon of the *Biceps brachii* and is continued into the forearm as the *lateral antibrachial cutaneous nerve*. In its course through the arm it supplies the *Coracobrachialis*, *Biceps brachii*, and the greater part of the *Brachialis*. The branch to the *Coracobrachialis* is given off from the musculocutaneous nerve before that nerve enters the muscle; it receives its fibres from the seventh cervical nerve, and in some instances arises directly from the outer cord of the plexus. The branches to the *Biceps brachii* and *Brachialis* arise from the musculocutaneous nerve after it has pierced the *Coracobrachialis*; that supplying the *Brachialis* gives a filament to the elbow-joint. The nerve also sends a small branch to the humerus which enters the bone with the nutrient artery.

The *lateral antibrachial cutaneous nerve* (fig. 837) passes behind the cephalic vein, and descends along the radial border of the forearm to the wrist. It supplies the skin over the lateral half of the volar surface of the forearm and distributes branches which turn round the radial border of the forearm to communicate with the dorsal antibrachial cutaneous nerve and the superficial branch of the radial nerve. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the dorsal surface of the carpus. The nerve then passes downwards to the ball of the thumb, where it ends in cutaneous filaments. It communicates with the superficial branch of the radial nerve, and with the palmar cutaneous branch of the median nerve.

The musculocutaneous nerve presents frequent irregularities. It may adhere for some distance to the median nerve and then pass beneath the *Biceps brachii* instead of through the *Coracobrachialis*. Some of the fibres of the median nerve may run for some distance in the musculocutaneous nerve and then leave it to join their proper trunk; less frequently the reverse is the case, and the median nerve sends a branch to join the musculocutaneous nerve. The nerve may pass under the *Coracobrachialis* or through the *Biceps brachii*. Occasionally it gives a filament to the *Flexor teres*. It supplies the dorsal surface of the thumb when the superficial branch of the radial nerve is absent.

The medial antibrachial cutaneous nerve (internal cutaneous nerve) (fig. 841) arises from the medial cord of the brachial plexus. It derives its fibres from the eighth cervical and first thoracic nerves, and at its commencement is placed between the axillary artery and vein. It gives off, near the

FIG. 839.—The cutaneous nerves of the right upper extremity. Posterior view.

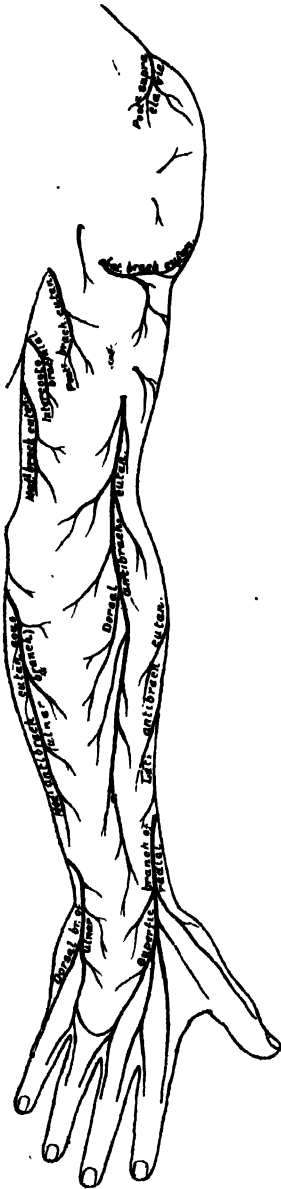
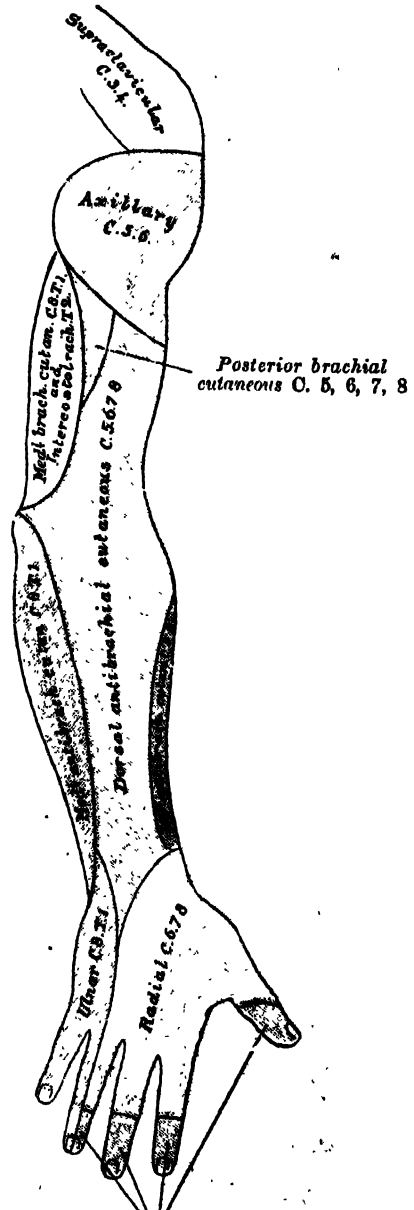


FIG. 840.—A diagram of the segmental distribution of the cutaneous nerves of the right upper extremity. Posterior view.



Median C. 5, 6, 7, 8

axilla, a filament which pierces the fascia and supplies the skin covering the Biceps brachii, almost as far as the elbow. The nerve then runs down the arm on the medial side of the brachial artery, pierces the deep fascia with the basilic vein, about the middle of the arm, and divides into a volar and an ulnar branch.

The *volar branch*, the larger, passes usually in front of, but occasionally behind, the median cubital vein (median basilic vein). It then descends on the front of the medial side of the forearm, distributing filaments to the skin as far as the wrist, and communicating with the palmar cutaneous branch of the ulnar nerve (fig. 837).

The *ulnar branch* passes obliquely downwards on the medial side of the basilic vein, in front of the medial epicondyle of the humerus, to the back of the forearm, and descends on its medial side as far as the wrist, distributing filaments to the skin. It communicates with the medial brachial cutaneous nerve, the dorsal antibrachial cutaneous branch of the radial nerve, and the dorsal branch of the ulnar nerve (fig. 839).

The *medial brachial cutaneous nerve* (lesser internal cutaneous nerve, or nerve of Wrisberg) is distributed to the skin on the medial side of the arm (fig. 835). It is the smallest branch of the brachial plexus, and, arising from the medial cord, receives its fibres from the eighth cervical and first thoracic nerves. It passes through the axilla and crosses in front of, or behind, the axillary vein. It then runs on the medial side of this vein, and communicates with the intercostobrachial nerve. It descends along the medial side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the skin of the back of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the skin in front of the medial epicondyle, and others over the olecranon. It communicates with the ulnar branch of the medial antibrachial cutaneous nerve.

In some cases the medial brachial cutaneous and intercostobrachial nerves are connected by two or three filaments, which form a plexus in the axilla. In other cases the intercostobrachial nerve is large and may be reinforced by a part of the lateral cutaneous branch of the third intercostal nerve; it then takes the place of the medial brachial cutaneous nerve, receiving from the brachial plexus a communicating filament which represents the latter nerve; in a few cases this filament is wanting.

The *median nerve* (fig. 841) arises by two roots, one from the lateral and one from the medial cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front of or laterally to that vessel. Its fibres are derived from the sixth, seventh, and eighth cervical and first thoracic nerves. As it descends through the arm, it lies at first laterally to the brachial artery; about the level of the insertion of the Coracobrachialis it crosses the artery, usually in front of, but occasionally behind it, and lies on its medial side at the bend of the elbow, where it is situated behind the lacertus fibrosus (bicipital fascia), and is separated from the elbow-joint by the Brachialis. It enters the forearm between the two heads of the Pronator teres and then crosses the ulnar artery, but is separated from this vessel by the deep head of the Pronator teres. It descends beneath the Flexor digitorum sublimis, lying on the Flexor digitorum profundus, to within 5 cm. of the transverse carpal ligament; here it becomes more superficial, and is situated between the tendons of the Flexor digitorum sublimis and Flexor carpi radialis. In this situation it lies behind, and rather to the lateral side of, the tendon of the Palmaris longus, and is covered by the skin and fascia. It then passes behind the transverse carpal ligament into the palm of the hand. In its course through the forearm it is accompanied by the median artery, a branch of the volar interosseous artery.

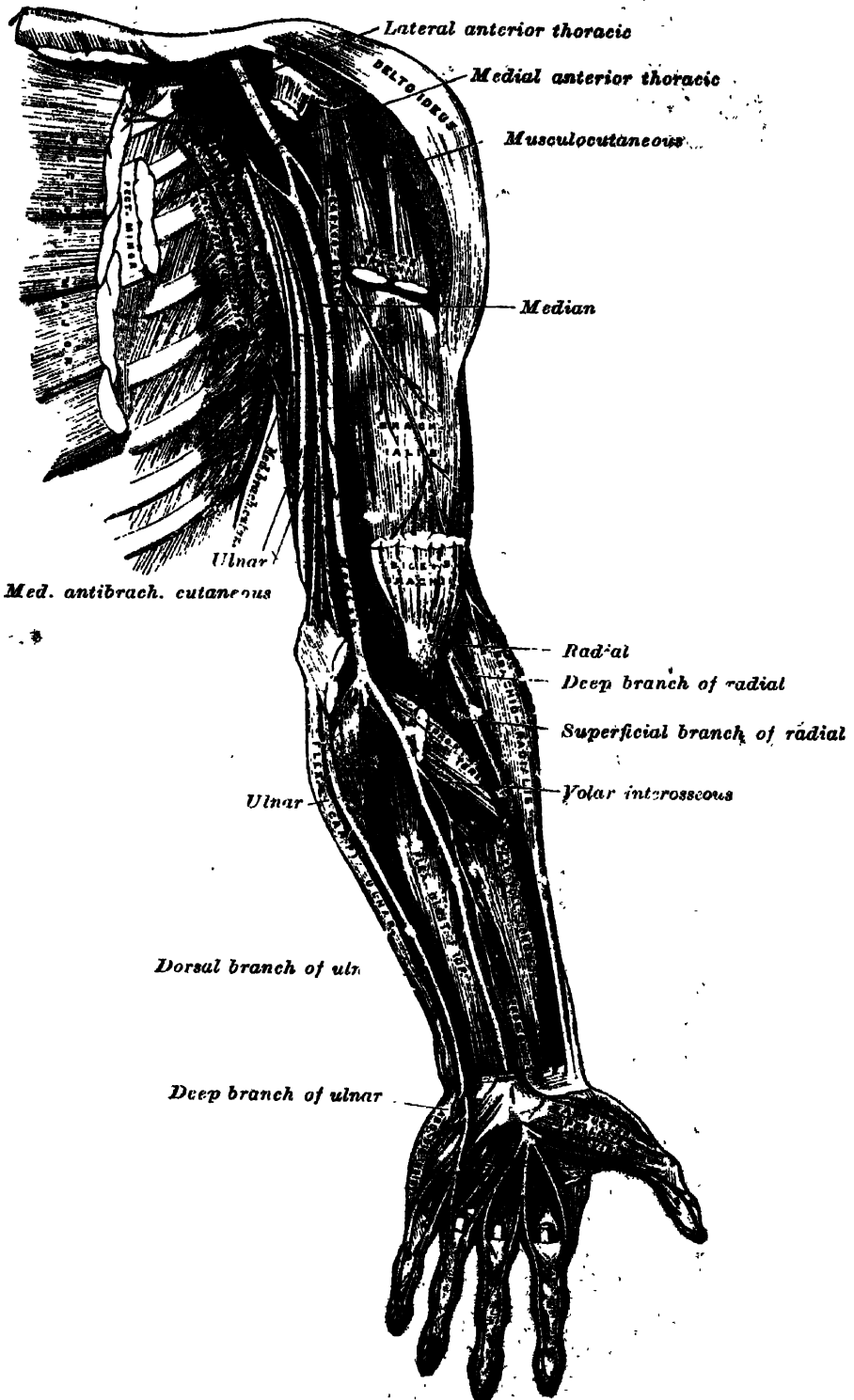
Branches.—With the exception of the nerve to the Pronator teres, which derives its fibres from the sixth cervical nerve, and usually arises above the elbow-joint, the median nerve gives off no branches in the arm. As it passes in front of the elbow, it supplies one or two twigs to the joint.

In the forearm its branches are: muscular, volar interosseous, and palmar.

The *muscular branches* are derived from the nerve near the elbow and supply all the superficial muscles on the front of the forearm, except the Flexor carpi ulnaris.

The *volar interosseous nerve* (anterior interosseous nerve) supplies the deep muscles on the front of the forearm, except the ulnar half of the Flexor digitorum profundus. It accompanies the volar interosseous artery along the front of the antibrachial interosseous membrane, in the interval between the Flexor pollicis longus and Flexor digitorum profundus, supplying the whole

FIG. 841.—The nerves of the left upper extremity.



of the former and the lateral half of the latter muscle; it sends branches into the deep surface of the Pronator quadratus, and ends in the wrist-joint.

The *palmar branch* of the median nerve arises at the lower part of the forearm. It pierces the volar carpal ligament, and divides into a lateral and a medial branch; the lateral branch supplies the skin over the ball of the thumb, and communicates with the volar branch of the lateral antibrachial cutaneous nerve; the medial branch supplies the skin of the palm, and communicates with the palmar cutaneous branch of the ulnar nerve.

In the *palm of the hand* the median nerve is covered by the skin, the palmar aponeurosis and the superficial volar arch, and rests on the tendons of the flexor muscles. Immediately after emerging from under the transverse carpal ligament it becomes enlarged and flattened and splits into a lateral and a medial portion. The *lateral* portion of the nerve supplies a short, stout branch to certain of the muscles of the ball of the thumb, viz. the Abductor brevis, the Opponens, and the superficial head of the Flexor brevis, and then divides into three *proper volar digital nerves*; two of these supply the sides of the thumb, while the third gives a twig to the first Lumbricalis and is distributed to the radial side of the index finger. The *medial* portion of the nerve divides into two *common volar digital nerves*. The first of these gives a twig to the second Lumbricalis and runs towards the cleft between the index and middle fingers, where it divides into two proper digital nerves for the adjoining sides of these digits. The second runs towards the cleft between the middle and ring fingers, and splits into two proper digital nerves for the adjoining sides of these digits; it communicates with a branch from the ulnar nerve, and sometimes sends a twig to the third Lumbricalis.

Opposite the base of the first phalanx each proper digital nerve gives off a dorsal branch which joins the dorsal digital nerve from the superficial branch of the radial nerve, and supplies the skin on the dorsal surface of the last phalanx. At the end of the digit the digital nerve divides into two branches, one of which supplies the tip of the finger, the other ramifies around and beneath the nail. On the fingers the proper digital nerves are superficial to the corresponding arteries.

The *ulnar nerve* (fig. 841) arises from the medial cord of the brachial plexus, and derives its fibres from the eighth cervical and first thoracic nerves. It lies medially to the axillary artery, and to the brachial artery as far as the middle of the arm. Here it pierces the medial intermuscular septum, runs obliquely across the medial head of the Triceps brachii, and descends to the groove between the medial epicondyle and the olecranon, accompanied by the superior ulnar collateral artery. At the elbow, it lies in the sulcus nervi ulnaris on the back of the medial epicondyle, and enters the forearm between the two heads of the Flexor carpi ulnaris. It descends along the medial side of the forearm, lying upon the Flexor digitorum profundus; its upper half is covered by the Flexor carpi ulnaris, its lower half lies on the lateral side of the muscle, covered by the skin and fascia. In the upper third of the forearm, it is separated from the ulnar artery by a considerable interval, but in the rest of its extent lies close to the medial side of the artery. About 5 cm. above the wrist it divides into a dorsal and a volar branch.

The branches of the ulnar nerve are: articular to the elbow-joint, muscular, palmar cutaneous, dorsal, and volar.

The *articular branches* to the elbow-joint are several small filaments which arise from the nerve as it lies between the medial epicondyle and olecranon.

The *muscular branches*, two in number, arise near the elbow; one supplies the Flexor carpi ulnaris; the other, the medial half of the Flexor digitorum profundus.

The *palmar cutaneous branch* arises about the middle of the forearm, and descends on the ulnar artery, giving off some filaments to the vessel. It perforates the volar carpal ligament and ends in the skin of the palm, communicating with the palmar branch of the median nerve.

The *dorsal branch* arises about 5 cm. above the wrist; it passes backwards beneath the Flexor carpi ulnaris, perforates the deep fascia, and, running along the medial side of the back of the wrist and hand, divides into two dorsal digital branches: one supplies the medial side of the little finger; the other, the adjacent sides of the little and ring fingers. It also sends a twig to the

that given by the superficial branch of the radial nerve for the adjoining sides of the middle and ring fingers, and assists in supplying them. A branch is distributed to the metacarpal region of the hand, communicating with a twig of the superficial branch of the radial nerve (fig. 839). On the little finger the dorsal digital branches extend only as far as the base of the terminal phalanx, and on the ring finger as far as the base of the second phalanx; the more distal parts of these digits are supplied by dorsal branches derived from the proper volar digital branches of the ulnar nerve.

The *volar branch* crosses the transverse carpal ligament on the lateral side of the pisiform bone, medially to and a little behind the ulnar artery. It ends by dividing into a superficial and a deep branch. The *superficial branch* supplies the Palmaris brevis and the skin on the medial side of the hand, and divides into a proper volar digital branch for the medial side of the little finger, and a common volar digital branch which sends a twig to join the median nerve and then divides into two proper digital nerves for the adjoining sides of the little and ring fingers (fig. 837). The proper digital branches are distributed to the fingers in the same manner as those of the median. The *deep branch*, accompanied by the deep branch of the ulnar artery, passes between the Abductor digiti quinti and Flexor digiti quinti brevis; it then perforates the Opponens digiti quinti and follows the course of the deep volar arch beneath the flexor tendons. At its origin it supplies the three short muscles of the little finger. As it crosses the hand, it supplies all the Interossei and the third and fourth Lumbricales; it ends by supplying the Adductor pollicis and the deep portion of the Flexor pollicis brevis. It also sends articular filaments to the wrist-joint.

It has been pointed out that the medial part of the Flexor digitorum profundus is supplied by the ulnar nerve; the third and fourth Lumbricales, which are connected with the tendons of this part of the muscle, are supplied by the same nerve. In like manner the lateral part of the Flexor digitorum profundus and the first and second Lumbricales are supplied by the median nerve. The third Lumbricalis frequently receives an additional twig from the median nerve.

The *radial nerve* (musculospiral nerve) (fig. 842), the largest branch of the brachial plexus, derives its fibres from the fifth, sixth, seventh, and eighth cervical and first thoracic nerves. It descends behind the third part of the axillary artery and the upper part of the brachial artery, and in front of the tendons of the Latissimus dorsi and Teres major. It then winds with the arteria profunda brachii from the medial to the lateral side of the humerus in the sulcus nervi radialis (musculospiral groove) between the medial and lateral heads of the Triceps brachii. It pierces the lateral intermuscular septum, and passes between the Brachialis and Brachioradialis to the front of the lateral epicondyle, where it divides into a superficial and a deep branch.

The branches of the radial nerve are: muscular, cutaneous, superficial, and deep.

The *muscular branches* supply the Triceps brachii, Anconeus, Brachioradialis, Extensor carpi radialis longus, and Brachialis, and are grouped as medial, posterior, and lateral.

The medial muscular branches supply the medial and long heads of the Triceps brachii. That to the medial head is a long, slender filament, which lies close to the ulnar nerve as far as the lower third of the arm, and is therefore frequently spoken of as the *ulnar collateral nerve*.

The posterior muscular branch, of large size, arises from the part of the nerve which lies in the sulcus nervi radialis. It divides into filaments which supply the medial and lateral heads of the Triceps brachii and the Anconeus. The branch for the latter muscle is a long nerve, which descends in the substance of the medial head of the Triceps brachii, to which it gives numerous branches. It is accompanied by the middle collateral branch of the arteria profunda brachii, and crosses the back of the elbow-joint to end in the Anconeus.

The lateral muscular branches supply the Brachioradialis, Extensor carpi radialis longus, and the lateral part of the Brachialis.

The *cutaneous branches* are two in number, the posterior brachial cutaneous and the dorsal antibrachial cutaneous.

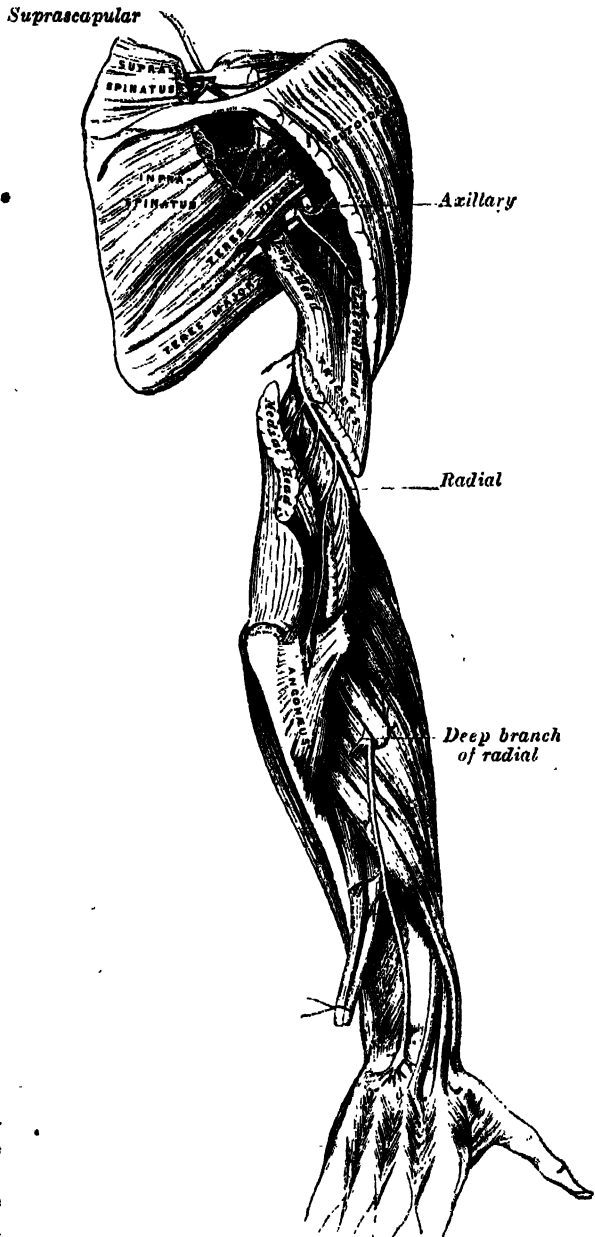
The *posterior brachial cutaneous nerve* (internal cutaneous branch of the musculospiral nerve), of small size, arises in the axilla. It passes to the medial side of the arm and supplies the skin on its dorsal surface nearly as far as the olecranon. It crosses posterior to, and communicates with, the intercostobrachial nerve.

The *dorsal antibrachial cutaneous nerve* (external cutaneous branch of musculospiral nerve) perforates the lateral head of the *Triceps brachii* at its attachment to the humerus. The *upper* and smaller branch of the nerve passes to the front of the elbow, lying close to the cephalic vein, and supplies the skin of the lateral part of the lower half of the arm (fig. 837). The *lower* branch pierces the deep fascia below the insertion of the *Deltoides*, and descends along the lateral side of the arm and elbow, and then along the back of the forearm to the wrist, supplying the skin in its course, and joining, near its termination, with dorsal branches of the lateral antibrachial cutaneous nerve (fig. 839).

The *superficial branch of the radial nerve* (radial nerve) passes along the front of the lateral side of the forearm to the commencement of its lower third. It lies at first upon the *Supinator*, laterally to the radial artery, and concealed beneath the *Brachioradialis*. In the middle third of the forearm, it lies behind the same muscle, close to the lateral side of the artery. It quits the artery about

7 cm. above the wrist, passes beneath the tendon of the *Brachioradialis*, and, piercing the deep fascia, divides into a lateral and a medial branch (fig. 839). The *lateral branch*, the smaller, supplies the skin of the radial side and ball of the thumb, joining with branches of the lateral antibrachial cutaneous nerve. The *medial branch* communicates, above the wrist, with dorsal branches of the lateral antibrachial cutaneous nerve, and, on the back of the hand, with the dorsal branch of the ulnar nerve. It then divides into four digital nerves, which are distributed as follows: the first supplies the medial side of the

FIG. 842.—The suprascapular, axillary, and radial nerves.



thumb; the second, the lateral side of the index finger; the third, the adjoining sides of the index and middle fingers; the fourth communicates with a filament from the dorsal branch of the ulnar nerve, and supplies the adjoining sides of the middle and ring fingers.*

The deep branch of the radial nerve (posterior interosseous nerve) winds to the back of the forearm round the lateral side of the radius between the two planes of fibres of the Supinator. Before reaching the back of the limb it gives a branch to the Extensor carpi radialis brevis, and another to the Supinator, and as it traverses this latter muscle it supplies additional branches to it. As it escapes from the Supinator on the back of the forearm it gives three short branches to the Extensor digitorum communis, Extensor digiti quinti proprius and Extensor carpi ulnaris, and two long branches—a medial to the Extensor pollicis longus and the Extensor indicis proprius, and a lateral which supplies the Abductor pollicis longus and ends in the Extensor pollicis brevis. The nerve, now diminished to a fine thread, descends, as the *dorsal interosseous nerve*, on the antibrachial interosseous membrane, in front of the Extensor pollicis longus, to the back of the carpus, where it presents a gangliform enlargement from which filaments are distributed to the ligaments and articulations of the carpus.

Applied Anatomy.—The brachial plexus may be injured by falls from a height on to the side of the head and shoulder, whereby the nerves of the plexus are violently stretched; the fifth cervical nerve sustains the greatest amount of injury, and the subsequent paralysis may be confined to the muscles supplied by this nerve, viz. the Deltoides, Biceps brachii, Brachialis, and Brachioradialis, with sometimes the Supraspinatus, Infraspinatus and Supinator. The position of the limb, under such conditions, is characteristic: the arm hangs by the side and is rotated inwards; the forearm is extended and pronated. The arm cannot be raised from the side; all power of flexion of the elbow is lost, as is also supination of the forearm. This is known as Erb's paralysis, and a very similar condition is occasionally met with in new-born children, either from injury to the fifth nerve from the pressure of forceps used in effecting delivery, or from traction of the head in breech presentations. A second variety of partial palsy of the brachial plexus is known as Kumpke's paralysis. In this it is the eighth cervical and first thoracic nerves that are injured, either before or after they have joined to form the lower trunk. Atrophy follows in the intrinsic muscles of the hand, and in the flexors of the fingers and wrist; the thenar and hypothenar eminences waste and flatten; the fingers cannot be spread out or approximated, on account of the paralysis of the Interossei, and become clawed. The injury to the nerves may follow direct violence or a gunshot wound.

The brachial plexus may also be injured by violent traction on the arm, or by efforts at reducing a dislocation of the shoulder joint; and the amount of paralysis will depend upon the amount of injury to the constituent nerves. When the entire plexus is involved, the whole of the upper extremity will be paralysed and anæsthetic. In these cases the injury appears to be rather a tearing away of the roots of the nerves from the medulla spinalis than a rupture of the nerves themselves. The brachial plexus in the axilla is often damaged from the pressure of a crutch, producing the condition known as 'crutch paralysis.' In these cases the radial (musculospiral) is the nerve most frequently implicated; the ulnar nerve suffers next in frequency. The median and radial nerves often suffer from 'sleep palsies,' paralysis from pressure coming on while the patient is profoundly asleep under the influence of alcohol or some narcotic.

Paralysis of the long thoracic nerve throws the Serratus anterior out of action, and may occur in porters in whom the nerve is exposed to injury as it crosses the posterior triangle of the neck. The inferior angle of the scapula is drawn towards the middle line, by the unopposed action of the Rhomboidei and Levator scapule, and tends to project backwards when the arm is held horizontally forwards. The arm cannot be raised above the horizontal unless the inferior angle of the scapula is pushed laterally for the patient.

The axillary (circumflex) nerve, on account of its course round the surgical neck of the humerus, is liable to be torn in fractures of this part of the bone, and in dislocations of the shoulder-joint; paralysis of the Deltoides, and anæsthesia of the skin over the lower part of that muscle, result. According to Erb, inflammation of the shoulder-joint is liable to be followed by a neuritis of this nerve from extension of the inflammation to it. Paralysis of the Deltoides renders abduction of the arm to the horizontal level impossible. The associated paralysis of the Teres minor is not easily demonstrated.

Hilton gave the axillary nerve as an illustration of a law which he laid down, that 'the same trunks of nerves whose branches supply the groups of muscles moving a joint

* According to Hutchison, the digital nerve to the thumb reaches only as high as the root of the nail; the one to the forefinger as high as the middle of the second phalanx; and those to the middle and ring fingers not higher than the first phalangeal joint. — *London Hospital Gazette*, vol. iii. p. 319.

furnish also a distribution of nerves to the skin over the insertions of the same muscles, and the interior of the joint receives its nerves from the same source.' In this way he explains the fact that an inflamed joint becomes rigid.

The *median nerve* is liable to injury in wounds of the forearm. In such cases there is loss of flexion of the second phalanges of all the fingers, and of the terminal phalanges of the index and middle fingers. Flexion of the terminal phalanges of the ring and little fingers is effected by that portion of the *Flexor digitorum profundus* which is supplied by the ulnar nerve. There is power to flex the proximal phalanges through the *Interossei*. The thumb cannot be flexed or opposed, and is maintained in a position of extension and adduction. There is loss in the power of pronating the forearm; the *Brachioradialis* has the power of bringing the forearm into a position of mid-pronation, but beyond this no further pronation can be effected. The wrist can be flexed, if the hand is first adducted by the action of the *Flexor carpi ulnaris*. There is loss or impairment of sensation on the volar surfaces of the thumb, index, middle, and radial half of the ring fingers, and on the dorsal surfaces of the same fingers over the last two phalanges; except in the thumb, where the loss of sensation would be limited to the back of the distal phalanx. In old cases the unopposed action of the *Interossei* produces backward dislocation of the interphalangeal joints. The thumb is extended and adducted to the index finger, cannot be flexed or abducted, and cannot be opposed to any one of the fingers; in consequence an 'ape-like' hand is produced. More commonly, however, the nerve is injured just above the annular ligament, when the power of flexion of the fingers and pronation of the forearm remains intact unless the *Flexor tendons* are also divided. This injury seriously interferes with the use of the hand, as, besides the wasting of the muscles of the thenar eminence, great trouble is experienced from the trophic changes which result about the skin and nails of the fingers, which are anæsthetic. In order to expose the median nerve, for the purpose of uniting the divided ends, supposing the injury to be just above the wrist, an incision should be made along the radial side of the tendon of the *Palmaris longus*, which serves as a guide to the nerve.

The *ulnar nerve* is also liable to be injured in wounds of the forearm, such injury leading to impaired power of ulnar flexion, and upon an attempt being made to flex the wrist, the hand is drawn to the radial side from paralysis of the *Flexor carpi ulnaris*; there is inability to spread out the fingers from paralysis of the *Interossei*, and for the same reason the fingers, especially the ring and little fingers, cannot be flexed at the metacarpophalangeal joints or extended at the interphalangeal joints, and the hand assumes a claw shape from the action of the opposing muscles; there is loss of power of flexion in the little and ring fingers; and there is inability to adduct the thumb. The muscles of the *hypothenar* eminence become wasted. Sensation is lost, or impaired, in the skin supplied by the nerve. In order to expose the nerve in the lower part of the forearm, an incision should be made along the radial border of the tendon of the *Flexor carpi ulnaris*, and the nerve will be found lying on the medial side of the ulnar artery. This nerve may be also affected in cases of dislocation of the shoulder or fracture of the surgical neck of the humerus. Wasting of the muscles which it supplies is not uncommonly seen where a 'cervical rib' is present; the lower end of the plexus passing between this and the first thoracic rib.

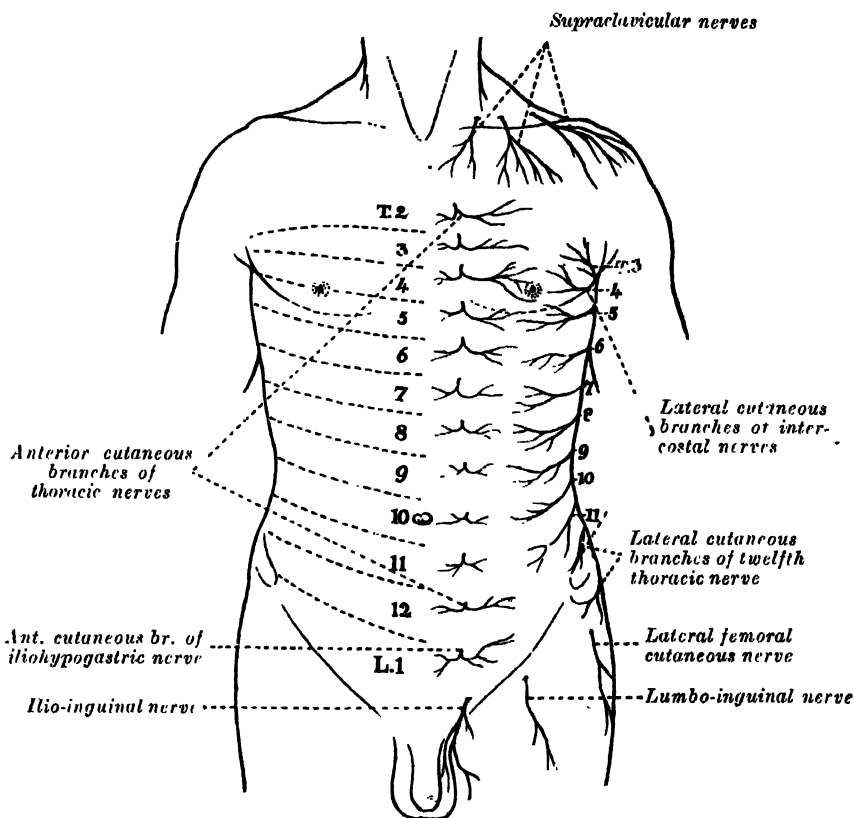
The *radial (musculospiral) nerve* is also frequently injured. In consequence of its close relationship to the humerus, it is often torn or injured in fractures of this bone, or subsequently involved in the callus that may be thrown out around a fracture, and thus pressed upon and its functions interfered with. It is also liable to be contused against the bone by kicks or blows, or to be divided in wounds of the arm. When paralysed, the hand is flexed at the wrist and lies flaccid. This is known as *wrist-drop*. The fingers are also flexed, and on an attempt being made to extend them, the last two phalanges only will be extended, through the action of the *Lumbricales* and *Interossei*; the first phalanges remaining flexed. There is no power of extending the wrist. Supination is completely lost when the forearm is extended on the arm, but is possible to a certain extent if the forearm be flexed so as to allow of the action of the *Biceps brachii*. The power of extension of the forearm is lost on account of paralysis of the *Triceps brachii*, if the injury to the nerve has taken place near its origin. In cases due to pressure, sensation is hardly affected; severe injury to the nerve occasions anæsthesia over the area supplied by the superficial branch of the radial nerve, and, if the lesion be high up, on the lateral side of the upper arm and the back of the forearm (posterior brachial and dorsal anti-brachial cutaneous branches) as well. The muscles supplied by the deep branch of the radial nerve are also particularly liable to be affected in chronic lead-poisoning; here the affection is probably in the cells of the anterior column of the medulla spinalis.

The nerve is best exposed by making an incision along the medial border of the *Brachioradialis*, just above the level of the elbow-joint. The skin and superficial fascia are to be divided and the deep fascia exposed. The white line in the fascia indicating the border of the muscle is to be defined, and the deep fascia divided in this line. On raising the *Brachioradialis*, the nerve will be found lying between it and the *Brachialis*. Incisions down to the neck of the radius posteriorly or on the lateral side should never be made, as the deep branch of the radial nerve would be severed.

ANTERIOR DIVISIONS OF THORACIC NERVES

The anterior divisions of the thoracic nerves (fig. 843) are twelve in number on either side. Eleven of them are situated between the ribs, and are therefore termed *intercostal*; the twelfth lies below the last rib. Each nerve is connected with the adjoining ganglion of the sympathetic trunk by a grey and a white ramus communicans. The intercostal nerves are distributed chiefly to the parietes of the thorax and abdomen, and differ from the anterior

FIG. 843.—A diagram of the distribution of the cutaneous nerves on the front of the trunk.



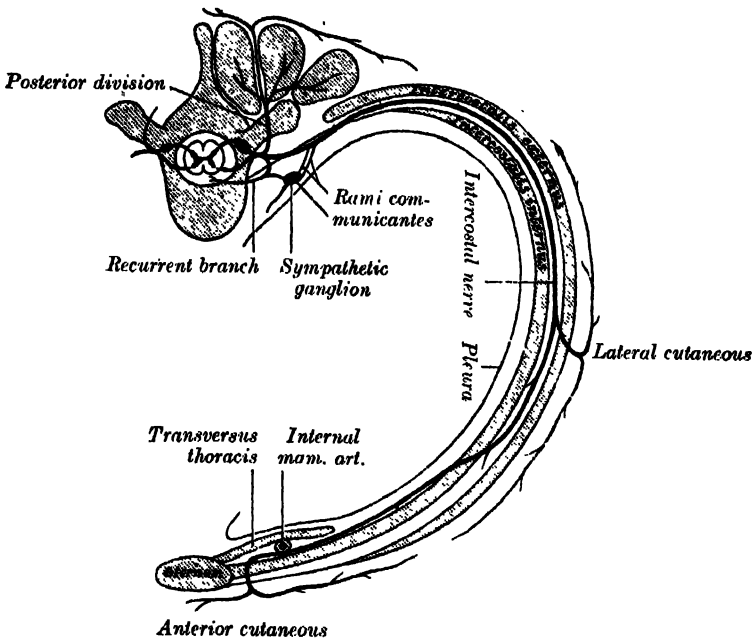
divisions of the other spinal nerves, in that each pursues an independent course, i.e. there is no plexus formation. The first two nerves supply fibres to the upper limb in addition to their thoracic branches; the next four are limited in their distribution to the parietes of the thorax; the lower five supply the parietes of the thorax and abdomen; the lower seven supply both motor and sensory fibres to the Diaphragm; the twelfth is distributed to the abdominal wall and the skin of the buttock.

The first thoracic nerve.—The anterior division of the first thoracic nerve divides into two branches: one, the larger, leaves the thorax in front of the neck of the first rib, and enters the brachial plexus (p. 895); the other and smaller branch, the *first intercostal nerve*, runs along the first intercostal space, and ends on the front of the chest as the first anterior cutaneous branch of the thorax. Occasionally this anterior cutaneous branch is wanting. The first intercostal nerve as a rule gives off no lateral cutaneous branch; but sometimes it sends a small branch to communicate with the intercostobrachial. The first

thoracic nerve frequently receives a connecting twig from the second nerve ; this twig ascends over the neck of the second rib.

The upper thoracic nerves.—The anterior divisions of the second, third, fourth, fifth, and sixth thoracic nerves, and the small branch from the first thoracic, are confined to the parietes of the thorax, and are named *thoracic intercostal nerves*. They pass forwards (fig. 844) in the intercostal spaces below the intercostal vessels. At the back of the chest they lie between the pleura and the posterior intercostal membranes, but soon pierce the latter and run between the two planes of intercostal muscles as far as the middle of the rib. They then enter the substance of the *Intercostales interni*, and, running amidst their fibres as far as the costal cartilages, they gain the inner surfaces of the muscles and lie between them and the pleura. Near the sternum, they cross in front of the internal mammary artery and *Transversus thoracis* muscle,

FIG. 844.—A diagram of the course and branches of a typical intercostal nerve.



pierce the *Intercostales interni*, the anterior intercostal membranes, and the *Pectoralis major*, and are now named the *anterior cutaneous nerves of the thorax* ; they supply the skin of the mamma and of the front of the thorax ; the branch from the second nerve unites with the anterior supraclavicular nerves of the cervical plexus.

Branches.—Numerous slender muscular filaments supply the *Intercostales*, the *Subcostales*, the *Levatores costarum*, the *Serratus posterior superior*, and the *Transversus thoracis*. At the front of the thorax some of these branches cross the costal cartilages from one intercostal space to another.

Each of these intercostal nerves, except the first, gives off a *lateral cutaneous* branch, about midway between the vertebral column and the sternum. These branches pierce the *Intercostales externi*, pass between the digitations of the *Serratus anterior*, and, with the exception of the lateral cutaneous branch of the second intercostal nerve, divide into anterior and posterior branches. The *anterior branches* run forwards over the border of the *Pectoralis major* and supply twigs to the skin and the mamma ; those of the fifth and sixth nerves supply twigs to the upper digitations of the *Obliquus externus abdominis*. The *posterior branches* run backwards, and supply the skin over the scapula and *Latissimus dorsi*.

The lateral cutaneous branch of the second intercostal nerve is named the *intercostobrachial nerve* (fig. 841). It crosses the axilla to the medial side of the arm, and joins with a filament from the medial brachial cutaneous nerve. It then pierces the fascia brachii, and supplies the skin of the upper half of the medial and posterior parts of the arm, communicating with the posterior brachial cutaneous branch of the radial nerve. The size of the intercostobrachial nerve is in inverse proportion to that of the medial brachial cutaneous nerve. A second intercostobrachial nerve is frequently given off from the lateral cutaneous branch of the third intercostal; it supplies filaments to the axilla and medial side of the arm.

The lower thoracic nerves.—The anterior divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves are continued anteriorly from the intercostal spaces into the abdominal wall; hence they are named *thoracico-abdominal intercostal nerves*. They have the same arrangement as the upper ones as far as the anterior ends of the intercostal spaces, where they pass behind the costal cartilages, and between the *Obliquus internus* and *Transversus abdominis*, and enter the sheath of the *Rectus abdominis*. They supply the *Rectus abdominis* and end as the *anterior cutaneous branches* which supply the skin of the front of the abdomen. The lower intercostal nerves supply the *Intercostales* and abdominal muscles, and the last three send branches to the *Serratus posterior inferior*. About the middle of their course they give off *lateral cutaneous branches*; these pierce the *Intercostales externi* and the *Obliquus externus abdominis*, in the same line as the lateral cutaneous branches of the upper thoracic nerves, and divide into anterior and posterior branches, which are distributed to the skin of the abdomen and back respectively; the anterior branches supply twigs to the digitations of the *Obliquus externus abdominis*, and extend downwards and forwards nearly as far as the margin of the *Rectus abdominis*; the posterior branches pass backwards to supply the skin over the *Latissimus dorsi*.

The anterior division of the twelfth thoracic nerve is larger than the others, and often gives a communicating branch to the first lumbar nerve. It accompanies the subcostal artery along the lower border of the twelfth rib, and passes under the lateral lumbocostal arch. It then runs in front of the *Quadratus lumborum*, perforates the posterior aponeurosis of the *Transversus*, and passes forwards between it and the *Obliquus internus*, to be distributed in the same manner as the lower intercostal nerves. It communicates with the iliohypogastric nerve of the lumbar plexus, and gives a branch to the *Pyramidalis*. The *lateral cutaneous branch* of the twelfth thoracic nerve is large, and does not divide into an anterior and a posterior branch. It pierces the *Obliquus internus* and *Obliquus externus*, gives a twig to the lowest slip of the latter muscle, descends over the iliac crest in front of the lateral cutaneous branch of the iliohypogastric nerve (fig. 851), and is distributed to the skin of the front part of the gluteal region, some of its filaments reaching as low as the greater trochanter.

Applied Anatomy.—The lower seven thoracic nerves and the iliohypogastric branch of the first lumbar nerve supply the skin of the abdominal wall. They run downwards and forwards fairly equidistant from each other. The sixth and seventh supply the skin over the 'pit of the stomach'; the eighth corresponds to about the position of the middle tendinous inscription of the *Rectus abdominis*; the tenth to the umbilicus; the iliohypogastric supplies the skin over the os pubis and subcutaneous inguinal ring. In many diseases affecting the nerve-trunks at or near their origins, the pain is referred to their peripheral terminations. Thus, in Pott's disease of the vertebræ, children often suffer from pain in the abdomen. When the irritation is confined to a single pair of nerves, the sensation complained of is often a feeling of constriction, as if a cord were tied round the abdomen, and in these cases the situation of the sense of constriction may serve to localise the disease in the vertebral column. In other cases where the bone disease is more extensive and two or more nerves are involved, a more general, diffused pain in the abdomen is felt.

Again, it must be borne in mind that the nerves which supply the skin of the abdomen supply also the planes of muscle which constitute the greater part of the abdominal wall. Hence, any irritation applied to the peripheral ends of the cutaneous branches in the skin of the abdomen is immediately followed by reflex contraction of the abdominal muscles. The supply of both muscles and skin from the same source is of importance in protecting the abdominal viscera from injury. A blow on the abdomen, even of a severe character, will do no injury to the viscera if the muscles are in a condition of firm contraction;

whereas in cases where the muscles have been taken unawares, and the blow has been struck while they were in a state of rest, an injury insufficient to produce any lesion of the abdominal wall has been attended with rupture of some of the abdominal contents. The importance, therefore, of immediate reflex contraction upon the receipt of an injury cannot be overestimated, and the intimate association of the cutaneous and muscular fibres in the same nerve produces a much more rapid response on the part of the muscles to any peripheral stimulation of the cutaneous filaments than would be the case if the two sets of fibres were derived from independent sources.

The nerves supplying the abdominal muscles and skin, derived from the lower intercostal nerves, are intimately connected with the sympathetic supplying the abdominal viscera through the lower thoracic ganglia from which the splanchnic nerves are derived. In consequence of this, in laceration of the abdominal viscera and in acute peritonitis, the muscles of the belly wall become firmly contracted, and thus as far as possible preserve the abdominal contents in a condition of rest.

ANTERIOR DIVISIONS OF LUMBAR NERVES

The anterior divisions of the lumbar nerves increase in size from the first to the last. They are joined, near their origins, by *grey rami communicantes* from the lumbar ganglia of the sympathetic trunk. These rami consist of long, slender branches which accompany the lumbar arteries round the sides of the vertebral bodies, beneath the Psoas major. Their arrangement is somewhat irregular: one ganglion may give rami to two lumbar nerves, or one lumbar nerve may receive rami from two ganglia. The first and second, and sometimes the third and fourth, lumbar nerves are each connected with the lumbar part of the sympathetic trunk by a *white ramus communicans*.

The nerves pass obliquely outwards behind the Psoas major, or between its fasciculi, distributing filaments to it and the Quadratus lumborum. The first three and the greater part of the fourth form the *lumbar plexus*. The smaller part of the fourth joins with the fifth to form the *lumbosacral trunk*, which assists in the formation of the sacral plexus. The fourth nerve is named the *nervus furcalis*, from the fact that it is subdivided between the two plexuses.*

LUMBAR PLEXUS

The lumbar plexus (fig. 845) is situated in the posterior part of the Psoas major, in front of the transverse processes of the lumbar vertebrae; it is formed by the anterior divisions of the first three, and the greater part of the anterior division of the fourth, lumbar nerves; the first lumbar receives a branch from the last thoracic nerve.

The mode in which it is arranged varies in different subjects, but the usual condition is the following. The first lumbar nerve, supplemented by a twig from the last thoracic, splits into an upper and a lower branch; the upper, larger branch divides into the *iliohypogastric* and *ilio-inguinal* nerves; the lower, smaller branch unites with a branch of the second lumbar to form the *genitofemoral nerve*. The remainder of the second nerve, and the third and fourth nerves, divide into ventral and dorsal divisions. The ventral division of the second unites with the ventral divisions of the third and fourth nerves to form the *obturator nerve*. The dorsal divisions of the second and third nerves each divide into a smaller and a larger branch, the smaller branches uniting to form the *lateral femoral cutaneous nerve*, and the larger branches joining with the dorsal division of the fourth nerve to form the *femoral nerve*. The accessory obturator, when it exists, arises from the ventral divisions of the third and fourth nerves.

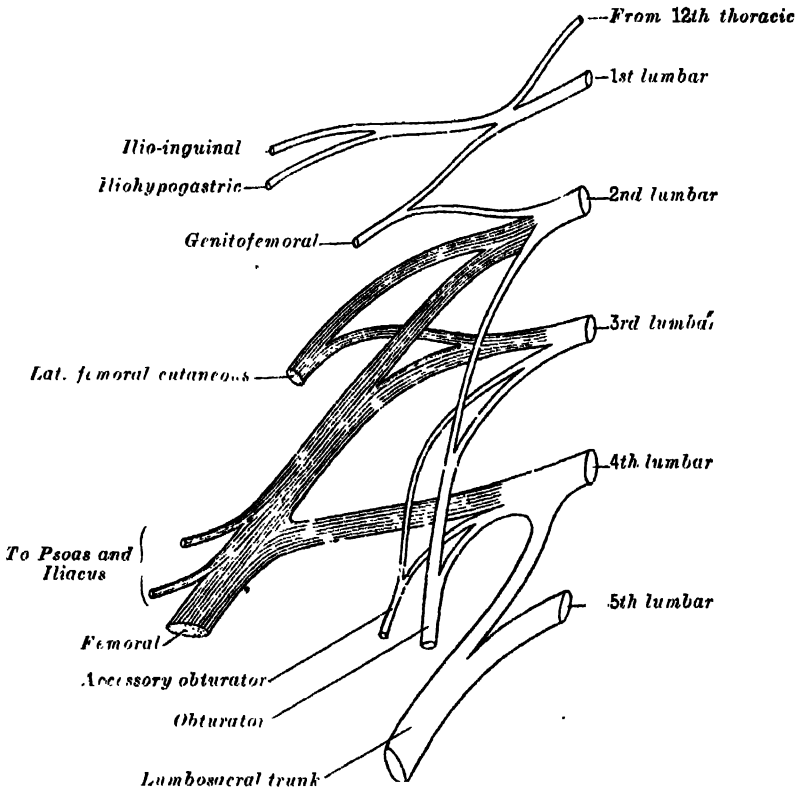
* In most cases the fourth lumbar is the *nervus furcalis*; but this arrangement is frequently departed from. The third is occasionally the lowest nerve which enters the lumbar plexus, giving at the same time some fibres to the sacral plexus, and thus forming the *nervus furcalis*; or both the third and fourth may be furcal nerves. When this occurs, the plexus is termed *high or propped*. More frequently the fifth nerve is divided between the lumbar and sacral plexuses, and constitutes the *nervus furcalis*; and when this takes place, the plexus is distinguished as a *low or pulled* plexus. These variations necessarily produce corresponding modifications in the sacral plexus.

The branches of the lumbar plexus may therefore be arranged as follows :

Iliohypogastric	. . . . .	1 L.
Ilio-inguinal	. . . . .	1 L.
Genitofemoral	. . . . .	1, 2 L.
		Dorsal divisions.
Lateral femoral cutaneous	. . . . .	2, 3 L.
Femoral	. . . . .	2, 3, 4 L.
		Ventral divisions.
Obturator	. . . . .	2, 3, 4 L.
Accessory obturator	. . . . .	3, 4 L.

The iliohypogastric nerve arises from the first lumbar nerve. It emerges from the upper part of the lateral border of the Psoas major, and crosses obliquely in front of the Quadratus lumborum to the iliac crest. It then

FIG. 845.—A plan of the lumbar plexus.



perforates the posterior part of the Transversus abdominis, and divides between that muscle and the Obliquus internus abdominis into a lateral and an anterior cutaneous branch.

The *lateral cutaneous branch* pierces the Obliquus internus and Obliquus externus immediately above the iliac crest at a point about 5 cm. behind the anterior superior iliac spine: it is distributed to the skin of the anterior part of the glutæal region, behind the lateral cutaneous branch of the last thoracic nerve (fig. 851).

The *anterior cutaneous branch* (fig. 843) runs between the Obliquus internus and Transversus, supplying twigs to both muscles. It then pierces the Obliquus internus at a point about 2 cm. on the medial side of the anterior superior iliac spine, perforates the aponeurosis of the Obliquus externus about 3 cm. above the subcutaneous inguinal ring, and is distributed to the skin of the abdomen above the os pubis.

The iliohypogastric nerve communicates with the last thoracic and ilio-inguinal nerves.

The ilio-inguinal nerve, smaller than the iliohypogastric nerve, arises with it from the first lumbar nerve. It emerges from the lateral border of the Psoas major just below the iliohypogastric nerve, and, passing obliquely across the Quadratus lumborum and Iliacus, perforates the Transversus abdominis, near the anterior part of the iliac crest, and communicates with the iliohypogastric nerve. It then pierces the Obliquus internus, distributing filaments to it, and, accompanying the spermatic cord through the subcutaneous inguinal ring, is distributed to the skin of the upper and medial part of the thigh, to the skin over the root of the penis and upper part of the scrotum in the male, and to the skin covering the mons pubis (mons Veneris) and labium majus in the female. The size of this nerve is in inverse proportion to that of the iliohypogastric. Occasionally it is very small, and ends by joining the iliohypogastric nerve; in such cases, a branch from the iliohypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent.

The genitofemoral nerve (genitocrural nerve) arises from the first and second lumbar nerves. It passes obliquely through the substance of the Psoas major, and emerges near its medial border, opposite the fibrocartilage between the third and fourth lumbar vertebræ; it then descends on the surface of the Psoas major, under cover of the peritoneum, and divides into the external spermatic and lumbo-inguinal nerves. The genitofemoral nerve frequently divides close to its origin, and the external spermatic and lumbo-inguinal nerves then emerge separately through the Psoas major.

The external spermatic nerve (genital branch of genitocrural) passes laterally on the Psoas major, and pierces the fascia transversalis, or passes through the abdominal inguinal ring; it then descends behind the spermatic cord, supplies the Cremaster, and gives a few filaments to the skin of the scrotum. In the female, it accompanies the round ligament of the uterus and ends in the skin of the mons pubis and labium majus.

The lumbo-inguinal nerve (crural branch of genitocrural) descends on the external iliac artery, sending a few filaments round it, and, passing beneath the inguinal ligament, enters the sheath of the femoral vessels, lying superficially and laterally to the femoral artery. It pierces the anterior layer of the sheath of the vessels and the fascia lata, and supplies a limited area of the skin on the anterior surface of the upper part of the thigh (fig. 846). On the front of the thigh it communicates with the anterior cutaneous branches of the femoral nerve. As the nerve runs beneath the inguinal ligament it gives a few twigs to the femoral artery.

The lateral femoral cutaneous nerve (external cutaneous nerve) arises from the dorsal divisions of the second and third lumbar nerves. It emerges from the lateral border of the Psoas major, and crosses the Iliacus obliquely, towards the anterior superior iliac spine. It then passes under the inguinal ligament and over the Sartorius muscle into the thigh, where it divides into an anterior and a posterior branch (fig. 846).

The anterior branch becomes superficial about 10 cm. below the inguinal ligament, and is distributed to the skin of the anterior and lateral parts of the thigh, as far as the knee. Its terminal filaments frequently communicate with the anterior cutaneous branches of the femoral nerve, and with the infrapatellar branch of the saphenous nerve, forming with them the *patellar plexus*.

The posterior branch pierces the fascia lata at a higher level than the anterior branch, and subdivides into filaments which pass backwards to supply the skin on the lateral surface of the limb, from the level of the greater trochanter to about the middle of the thigh.

The obturator nerve arises from the ventral divisions of the second, third, and fourth lumbar nerves; the branch from the third is the largest, while that from the second is often very small. It descends through the fibres of the Psoas major, and emerges from its medial border at the brim of the pelvis; it then passes behind the common iliac vessels, and on the lateral side of the hypogastric vessels, and runs along the lateral wall of the lesser pelvis, above and in front of the obturator vessels, to the upper part of the obturator foramen. Here it enters the thigh, and divides into an anterior and a posterior

branch, which are separated at first by a few fibres of the Obturator externus, and lower down by the Adductor brevis.

FIG. 846.—The cutaneous nerves of the right lower extremity. Front view.

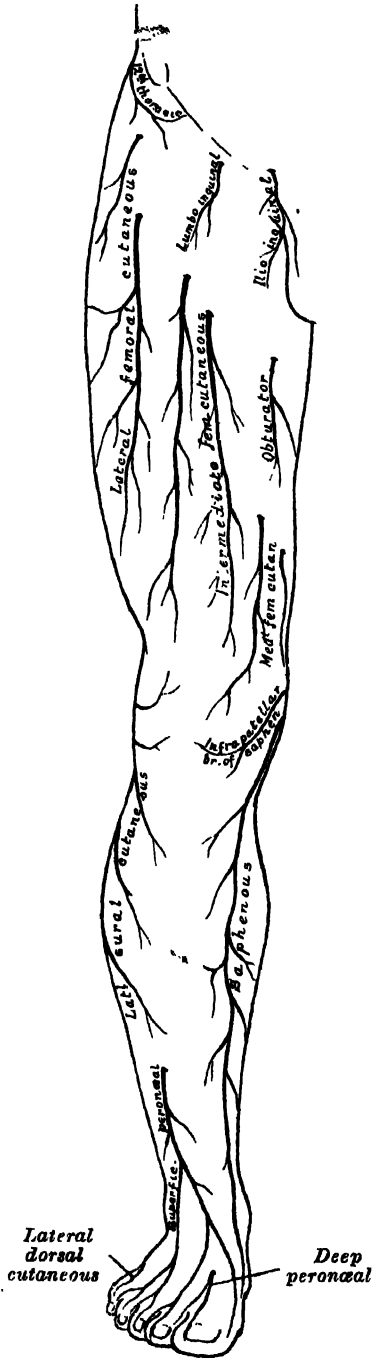
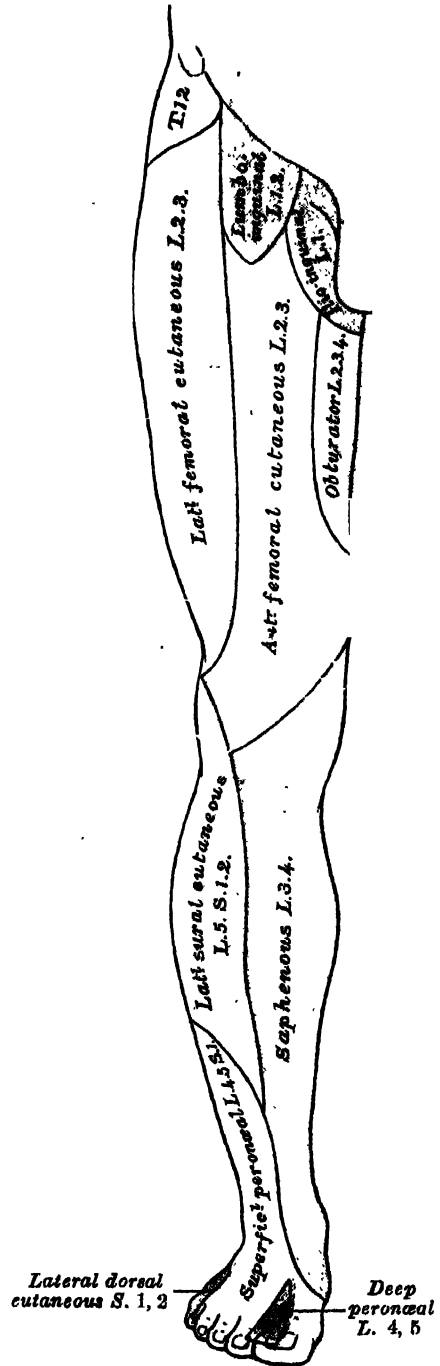


FIG. 847.—A diagram of the segmental distribution of the cutaneous nerves of the right lower extremity. Front view.



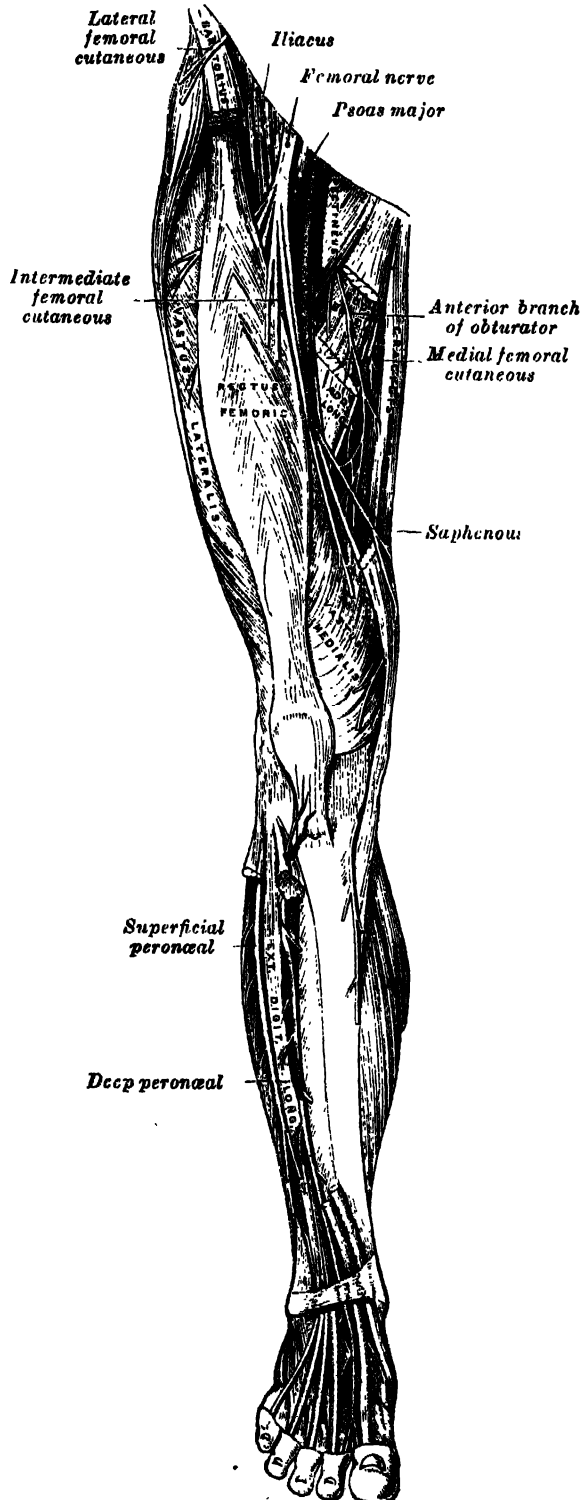
The anterior branch (fig. 848) leaves the pelvis in front of the Obturator externus and descends in front of the Adductor brevis, and behind the Pectineus and Adductor longus ; at the lower border of the latter muscle it communicates

with the anterior cutaneous and saphenous branches of the femoral nerve, forming a kind of plexus, which it is finally distributed. Near the obturator foramen the nerve gives off an articular branch to the hip-joint. Behind the Pectineus, it distributes branches to the Adductor longus and Gracilis, and usually to the Adductor brevis, and in rare cases to the Pectineus; it receives a filament from the ~~accessory~~ obturator nerve when that nerve is present.

Occasionally the communicating branch to the anterior cutaneous and saphenous branches of the femoral nerve is continued down, as a cutaneous branch, to the thigh and leg. When this is so, it emerges from beneath the lower border of the Adductor longus, descends along the posterior margin of the Sartorius to the medial side of the knee, where it pierces the deep fascia, communicates with the saphenous nerve, and is distributed to the skin half-way down the medial side of the leg.

The *posterior branch* pierces the anterior part of the Obturator externus, and supplies this muscle; it then passes behind the Adductor brevis on the front of the Adductor magnus, and divides into branches which are distributed to the Adductor magnus and to the Adductor brevis when the latter does not receive a branch from the anterior division of the nerve. It frequently gives off a slender *articular branch* to the knee-joint; this branch perforates the lower part of the Adductor magnus or passes through the opening which transmits the femoral artery, and enters the popliteal fossa; it here descends upon the popliteal artery, to the back of the knee-joint, where it pierces the oblique popliteal ligament, and is distributed to the articular capsule. It gives filaments to the popliteal artery.

FIG. 848.—The nerves of the right lower extremity. Front view.



The **accessory obturator nerve** (fig. 845) is present in about 20 per cent. of cases. It is of small size, and arises from the ventral divisions of the third and fourth lumbar nerves. It descends along the medial border of the Psoas major, crosses the superior ramus of the os pubis behind the Pectineus, and divides into branches. One branch enters the deep surface of the Pectineus; another goes to the hip-joint; while a third communicates with the anterior branch of the obturator nerve. Occasionally the accessory obturator nerve is very small, and supplies only the hip-joint; when the nerve is absent, the hip-joint receives two branches from the obturator nerve.

The **femoral nerve** (anterior crural nerve) (fig. 848), the largest branch of the lumbar plexus, arises from the dorsal divisions of the second, third, and fourth lumbar nerves. It descends through the fibres of the Psoas major, emerging from the muscle at the lower part of its lateral border, and passes down between it and the Iliacus, behind the iliac fascia; it then runs beneath the inguinal ligament, into the thigh, and splits into an anterior and a posterior division. Under the inguinal ligament, it is separated from the femoral artery by a portion of the Psoas major.

Within the abdomen the femoral nerve gives off small branches to the Iliacus, and a branch which is distributed upon the upper part of the femoral artery; the latter branch may arise in the thigh.

The anterior division of the femoral nerve gives off anterior cutaneous and muscular branches. The anterior cutaneous branches comprise the intermediate and medial cutaneous nerves (fig. 846).

The *intermediate cutaneous nerve* pierces the fascia lata about 8 cm. below the inguinal ligament, either as two branches, or as a single trunk which quickly divides into two branches; these branches descend vertically along the front of the thigh, and supply the skin as low as the knee. They end in the patellar plexus (p. 917). The lateral branch of the intermediate cutaneous communicates with the lumbo-inguinal branch of the genitofemoral nerve, and frequently pierces the Sartorius.

The *medial cutaneous nerve* lies at first on the lateral side of the femoral artery, but at the apex of the femoral triangle it crosses in front of the artery and divides into two branches, an anterior and a posterior. The *anterior branch* runs downwards on the Sartorius, perforates the fascia lata at the lower third of the thigh, and divides into two branches: one supplies the integument as low down as the medial side of the knee; the other crosses to the lateral side of the patella, communicating in its course with the infrapatellar branch of the saphenous nerve. The *posterior branch* descends along the medial border of the Sartorius to the knee, where it pierces the fascia lata, communicates with the saphenous nerve, and gives off several cutaneous branches. It then passes down to supply the skin of the medial side of the leg. Beneath the fascia lata, at the lower border of the Adductor longus, it joins to form a plexiform network (*subsartorial plexus*) with branches of the saphenous and obturator nerves. When the communicating branch from the obturator nerve is large and continued to the skin of the leg, the posterior branch of the medial cutaneous is small, and terminates in the plexus, occasionally giving off a few cutaneous filaments.

The medial cutaneous nerve, before dividing, gives off a few filaments, which pierce the fascia lata, to supply the skin of the medial side of the thigh, in the neighbourhood of the great saphenous vein; one of these filaments emerges through the fossa ovalis, and a second becomes subcutaneous about the middle of the thigh.

Muscular branches.—The *nerve to the Pectineus* arises just below the inguinal ligament, passes behind the femoral sheath and enters the anterior surface of the muscle; it is often duplicated. The *nerve to the Sartorius* arises in common with the intermediate cutaneous nerve.

The posterior division of the femoral nerve gives off the saphenous nerve, and muscular and articular branches.

The **saphenous nerve** (long or internal saphenous nerve) (fig. 848) is the largest cutaneous branch of the femoral nerve. It descends on the lateral side of the femoral artery and enters the adductor canal (p. 655) where it lies at first in front, and then on the medial side, of the femoral artery. At the lower end of the canal it quits the artery, and emerges through the aponeurotic

covering of the canal, accompanied by the saphenous branch of the highest genicular artery. It now descends vertically along the medial side of the knee behind the Sartorius, pierces the fascia lata, between the tendons of the Sartorius and Gracilis, and becomes subcutaneous. The nerve then passes along the tibial side of the leg, accompanied by the great saphenous vein, descends behind the medial border of the tibia, and, at the lower third of the leg, divides into two branches: one continues its course along the margin of the tibia, and ends at the ankle; the other passes in front of the ankle, and is distributed to the skin on the medial side of the foot, as far as the ball of the great toe, communicating with the medial branch of the superficial peroneal nerve.

Branches.—About the middle of the thigh, the saphenous nerve gives off a branch which joins the subsartorial plexus.

At the medial side of the knee it gives off a large *infrapatellar branch* (fig. 846) which pierces the Sartorius and fascia lata, and is distributed to the skin in front of the patella. This nerve communicates above the knee with the anterior cutaneous branches of the femoral nerve; below the knee, with other branches of the saphenous nerve; and, on the lateral side of the joint, with branches of the lateral femoral cutaneous nerve, forming a plexiform network, the *plexus patellæ*. The infrapatellar branch is occasionally small, and ends by joining the anterior cutaneous branches of the femoral nerve, which supply its place in front of the knee.

The *muscular branches* of the posterior division of the femoral nerve supply the four parts of the Quadriceps femoris. The branch to the Rectus femoris enters the upper part of the deep surface of the muscle, and supplies a filament to the hip-joint. The branch to the Vastus lateralis, of large size, accompanies the descending branch of the lateral femoral circumflex artery to the lower part of the muscle and sends an articular filament to the knee-joint. The branch to the Vastus medialis descends on the lateral side of the femoral vessels in company with the saphenous nerve. It enters the muscle about its middle, and gives off a filament, which can usually be traced downwards on the surface of the muscle, to the knee-joint. The branches to the Vastus intermedius, two or three in number, enter the anterior surface of the muscle about the middle of the thigh; a filament from one of these descends through the muscle to the Articularis genus and the knee-joint.

ANTERIOR DIVISIONS OF SACRAL AND COCCYGEAL NERVES

The anterior divisions of the sacral and coccygeal nerves form the sacral and pudendal plexuses. The anterior divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina, that of the fifth between the sacrum and coccyx, while that of the coccygeal nerve curves forwards below the rudimentary transverse process of the first piece of the coccyx. The first and second sacral nerves are large; the third, fourth, and fifth diminish progressively from above downwards; the coccygeal nerve is the smallest. Each of these six nerves receives a grey ramus communicans from the corresponding ganglion of the sympathetic trunk, while from the second, third, and fourth sacral nerves, white rami communicantes are given to the pelvic plexuses of the sympathetic.

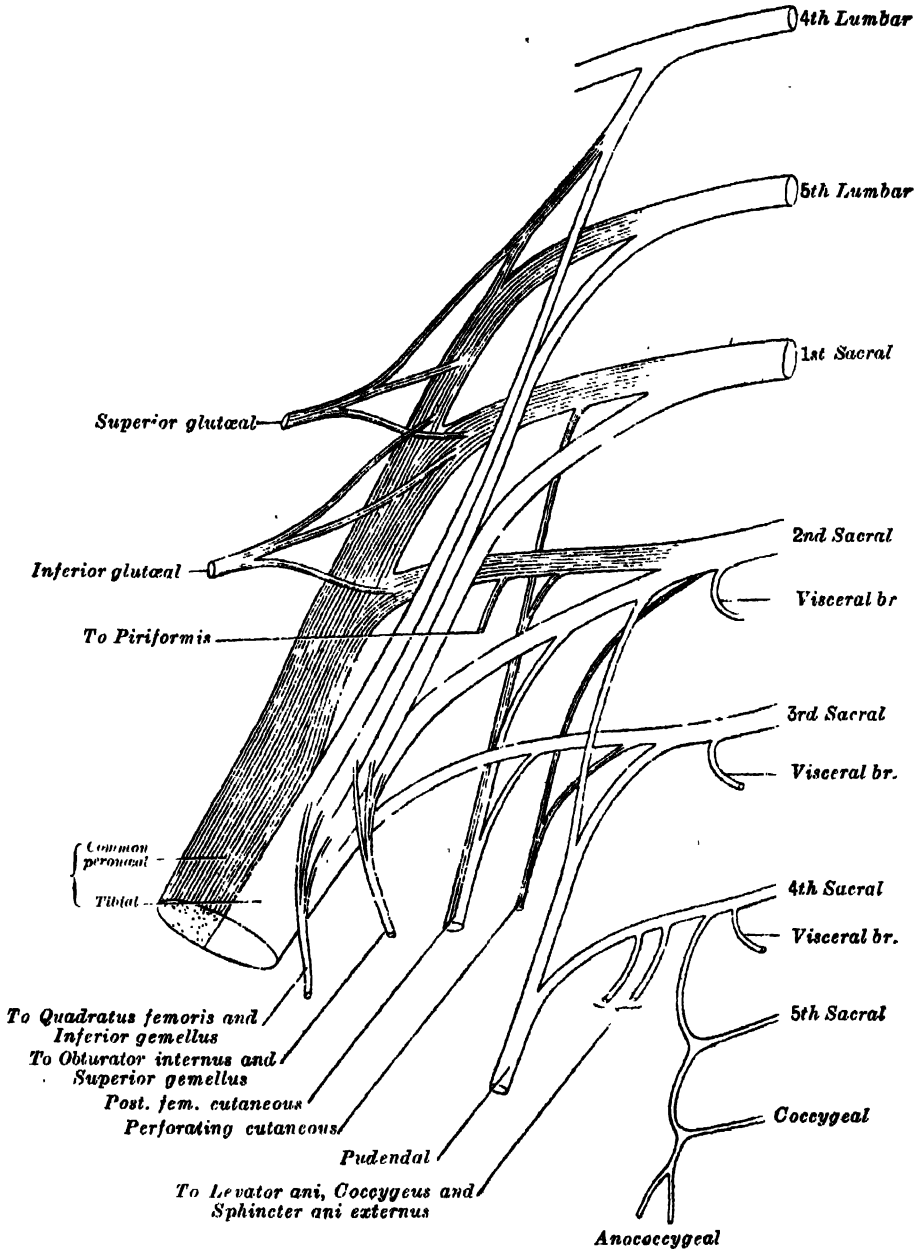
SACRAL PLEXUS

The *sacral plexus* (fig. 849) is formed by the lumbosacral trunk, the anterior division of the first, and portions of the anterior divisions of the second and third sacral nerves.

The lumbosacral trunk comprises the whole of the anterior division of the fifth and a part of that of the fourth lumbar nerve; it appears at the medial margin of the Psoas major and descends over the pelvic brim and in front of the sacro-iliac joint, to join the first sacral nerve. The anterior division of the third sacral nerve divides into an upper and a lower branch, the former entering the sacral plexus and the latter the pudendal plexus.

The nerves forming the sacral plexus converge towards the lower part of the greater sciatic foramen, and unite to form a flattened band, from the anterior and posterior surfaces of which several branches arise. The band itself is continued as the sciatic nerve, which splits on the back of the thigh

FIG. 849.—A plan of the sacral and pudendal plexuses.



into the tibial and common peroneal nerves. Sometimes these two nerves arise separately from the plexus, and in all cases their independence can be shown by dissection.

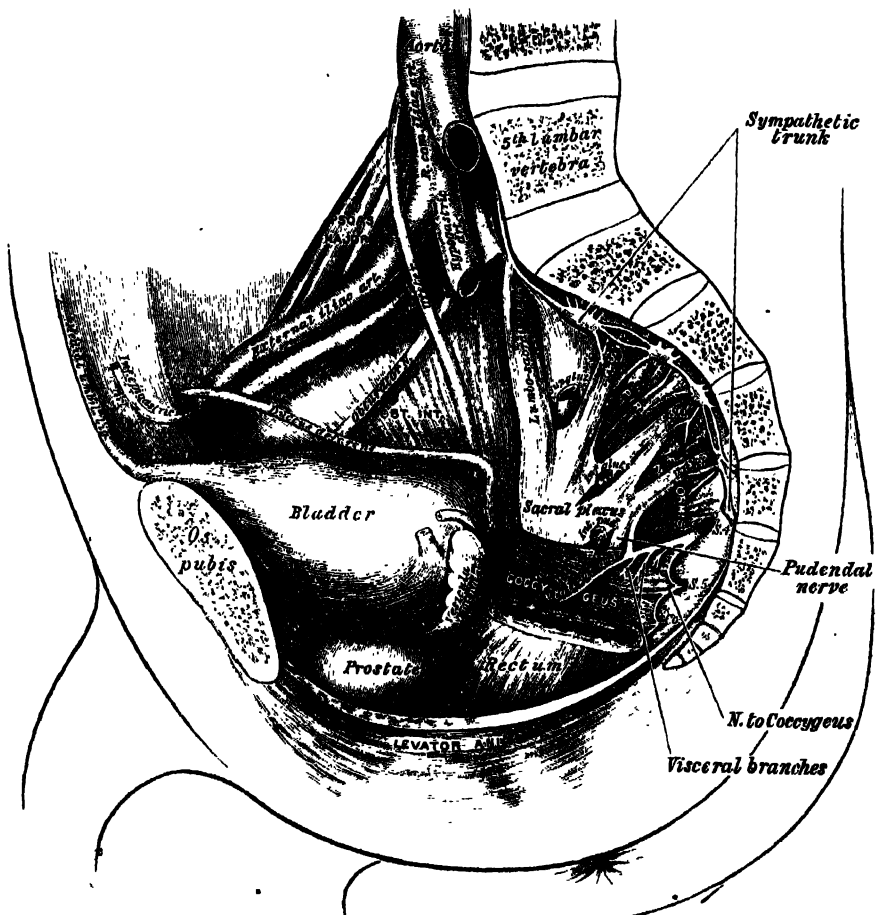
Relations.—The sacral plexus lies on the posterior wall of the pelvic cavity between the Piriformis and the pelvic fascia (fig. 850); in front of it are the hypogastric vessels, the ureter and the sigmoid colon. The superior gluteal vessels run between the lumbosacral trunk and the anterior division of the

first sacral nerve, and the inferior gluteal vessels between the anterior divisions of the second and third sacral nerves.

All the nerves entering the plexus, with the exception of the anterior division of the third sacral, split into ventral and dorsal divisions, and the nerves arising from these are as follows :

	Ventral divisions.	Dorsal divisions.
Nerve to Quadratus femoris and Gemellus inferior	4, 5 L., 1 S.	
Nerve to Obturator internus and Gemellus superior	5 L., 1, 2 S.	
Nerve to Piriformis		(1) 2 S.
Superior gluteal		4, 5 L., 1 S.
Inferior gluteal		5 L., 1, 2 S.
Posterior femoral cutaneous	2, 3 S.	1, 2 S.
Sciatic	4, 5 L., 1, 2, 3 S.	
Common peroneal		4, 5 L., 1, 2 S.

FIG. 850.—A dissection of the side wall of the pelvis, showing the sacral and pudendal plexuses.



The nerve to the Quadratus femoris and Gemellus inferior arises from the ventral divisions of the fourth and fifth lumbar and first sacral nerves : it leaves the pelvis through the greater sciatic foramen, below the Piriformis, and, running down on the ischium in front of the sciatic nerve, the Gemelli and the tendon of the Obturator internus, enters the anterior surfaces of the muscles ; it gives an articular branch to the hip-joint.

The nerve to the **Obturator internus** and **Gemellus superior** arises from the ventral divisions of the fifth lumbar and first and second sacral nerves. It leaves the pelvis through the greater sciatic foramen below the Piriformis, and gives off the branch to the **Gemellus superior**, which enters the upper part of the posterior surface of the muscle. It then crosses the ischial spine on the lateral side of the internal pudendal vessels, re-enters the pelvis through the lesser sciatic foramen, and pierces the pelvic surface of the **Obturator internus**.

The nerve to the **Piriformis** arises from the dorsal division of the second sacral nerve, or the dorsal divisions of the first and second sacral nerves, and enters the anterior surface of the muscle.

The **superior gluteal nerve** arises from the dorsal divisions of the fourth and fifth lumbar and first sacral nerves: it leaves the pelvis through the greater sciatic foramen above the Piriformis, accompanied by the superior gluteal vessels, and divides into a superior and an inferior branch. The *superior* branch accompanies the upper branch of the deep division of the superior gluteal artery and ends in the **Glutæus minimus**. The *inferior* branch runs with the lower branch of the deep division of the superior gluteal artery across the **Glutæus minimus**; it gives twigs to the **Glutæus medius** and **Glutæus minimus**, and ends in the **Tensor fasciæ latæ**.

The **inferior gluteal nerve** arises from the dorsal divisions of the fifth lumbar and first and second sacral nerves: it leaves the pelvis through the greater sciatic foramen below the Piriformis, and divides into branches which enter the deep surface of the **Glutæus maximus**.

The **posterior femoral cutaneous nerve** (small sciatic nerve) arises from the dorsal divisions of the first and second, and ventral divisions of the second and third sacral nerves, and issues from the pelvis through the greater sciatic foramen below the Piriformis. It then descends beneath the **Glutæus maximus** with the inferior gluteal artery, and runs down the back of the thigh beneath the fascia lata, and over the long head of the **Biceps femoris** to the back of the knee: here it pierces the deep fascia and accompanies the small saphenous vein to about the middle of the back of the leg, its terminal twigs communicating with the sural nerve.

Its branches are all cutaneous, and are distributed to the gluteal region, the perinæum, and the back of the thigh and leg.

The *gluteal branches* (nn. clunium inferiores), three or four in number, turn upwards round the lower border of the **Glutæus maximus**, and supply the skin covering the lower and lateral part of that muscle.

The *perinæal branches* are distributed to the skin at the upper and medial side of the thigh. One long perinæal branch (inferior pudendal) curves forwards below and in front of the ischial tuberosity, pierces the fascia lata, and runs forwards beneath the superficial fascia of the perinæum to the skin of the scrotum in the male, and of the labium majus in the female. It communicates with the inferior hæmorrhoidal and posterior scrotal nerves.

The *branches to the back of the thigh and leg* consist of numerous filaments derived from both sides of the nerve, and distributed to the skin covering the back and medial side of the thigh, the popliteal fossa, and the upper part of the back of the leg (fig. 851).

The **sciatic nerve** (fig. 853) is the largest nerve in the body. At its commencement it measures 2 cm. in breadth, and is the continuation of the flattened band of the sacral plexus. It passes out of the pelvis through the greater sciatic foramen, below the Piriformis muscle, descends between the greater trochanter of the femur and the tuberosity of the ischium, and along the back of the thigh to about its lower third, where it divides into two large branches, the tibial and common peronæal nerves. This division may take place at any point between the sacral plexus and the lower third of the thigh. When it occurs at the plexus, the common peronæal nerve usually pierces the Piriformis.

In the upper part of its course the nerve rests upon the posterior surface of the ischium, the nerve to the **Quadratus femoris**, the **Obturator internus** and **Gemelli**, and the **Quadratus femoris**; it is accompanied on its medial side by the posterior femoral cutaneous nerve and the inferior gluteal artery, and is covered by the **Glutæus maximus**. Lower down, it lies upon the **Adductor magnus**, and is crossed obliquely by the long head of the **Biceps femoris**.

The nerve gives off articular and muscular branches.

The *articular branches* arise from the upper part of the nerve and supply

FIG. 851.—The cutaneous nerves of the right lower extremity. Posterior view.

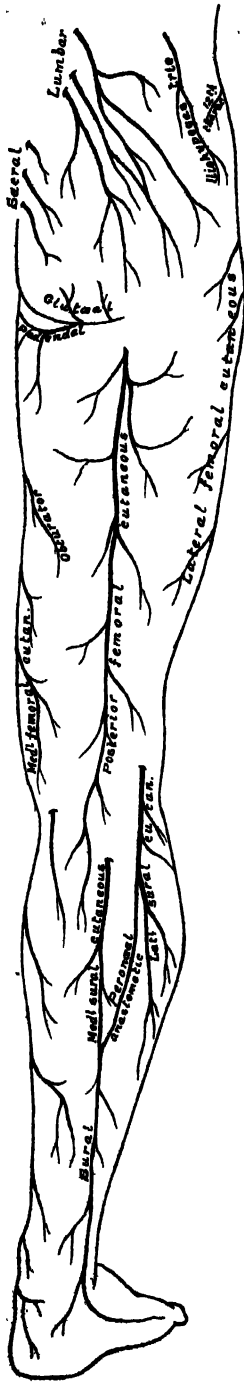
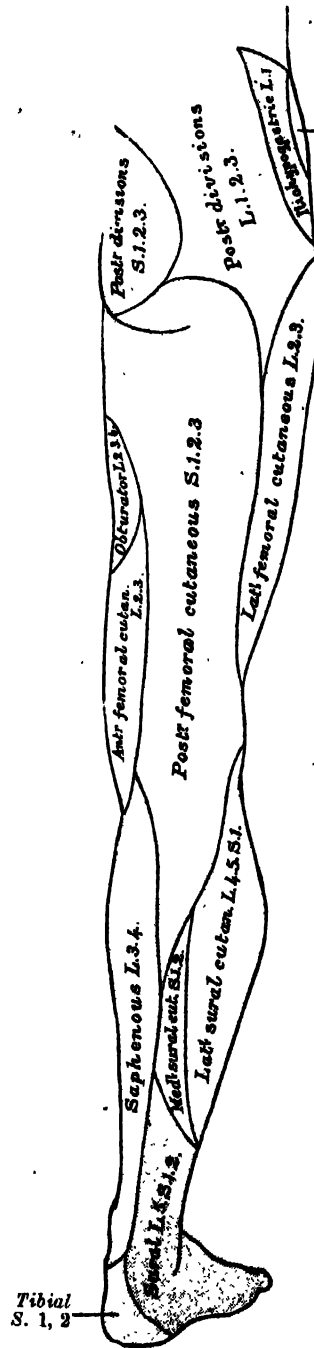


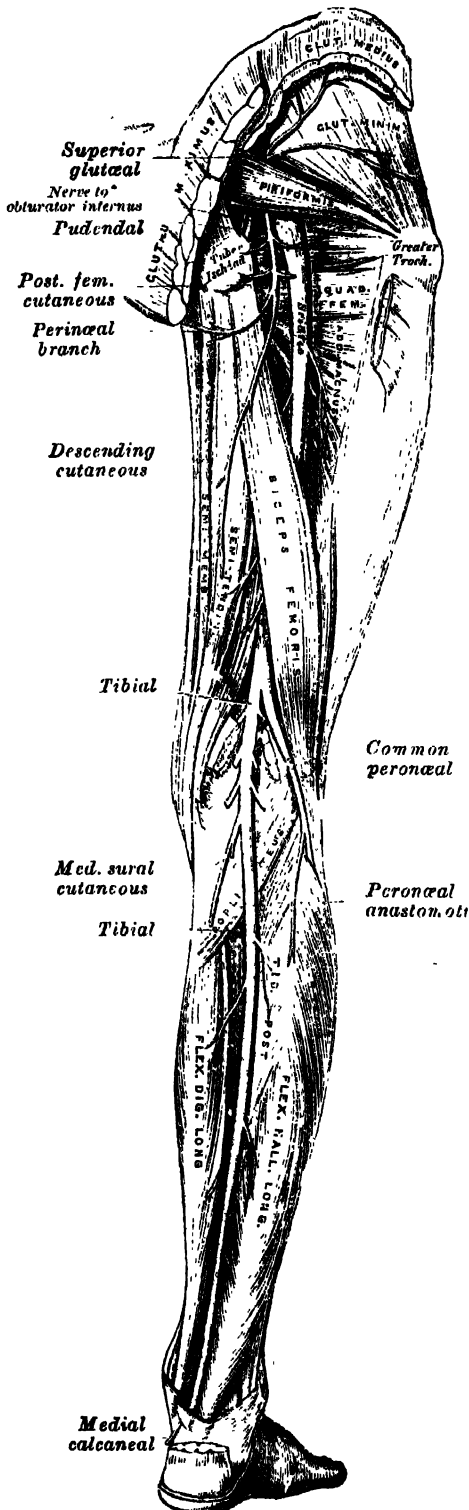
FIG. 852.—A diagram of the segmental distribution of the cutaneous nerves of the right lower extremity. Posterior view.



the hip-joint, perforating the posterior part of its capsule; they are sometimes derived from the sacral plexus.

The *muscular branches* are distributed to the Biceps femoris, Semitendinosus, Semimembranosus, and Adductor magnus. The nerve to the short head of the Biceps femoris comes from the common peroneal part of the sciatic.

FIG. 853.—The nerves of the right lower extremity.* Posterior view.



while the other muscular branches arise from the tibial portion, as may be seen in those cases where there is a high division of the sciatic nerve.

The tibial nerve (internal popliteal nerve) (fig. 853), the larger of the two terminal branches of the sciatic, arises from the ventral branches of the fourth and fifth lumbar and first, second, and third sacral nerves. It descends along the back of the thigh and through the middle of the popliteal fossa, to the lower part of the Popliteus muscle, whence it passes with the popliteal artery beneath the arch of the Soleus. It then runs along the back of the leg with the posterior tibial vessels to the interval between the medial malleolus and the heel, where it divides beneath the laciniato ligament into the medial and lateral plantar nerves. In the thigh it is overlapped by the hamstring muscles above, and then becomes more superficial, and lies laterally to, and some distance from, the popliteal vessels; opposite the knee-joint, it is superficial to these vessels, and then crosses to the medial side of the popliteal artery. In the leg it is covered in the upper part of its course by the superficial muscles of the calf; lower down by the skin and the superficial and deep fasciæ. It is placed on the deep muscles, and lies at first to the medial side of the posterior tibial artery, but soon crosses that vessel and descends on its lateral side as far as the ankle. In the lower third of the leg it runs parallel with the medial margin of the tendo calcaneus.

The branches of this nerve are: articular, muscular, medial sural cutaneous, medial calcaneal, medial and lateral plantar.

Articular branches, usually three in number, supply the knee-joint; two of these accompany the superior and inferior medial genicular arteries; and a third, the middle genicular artery. Just above its point of bifurcation the nerve gives an articular branch to the ankle-joint.

Muscular branches, four or five

* N.B.—In this diagram the medial sural cutaneous and peroneal anastomotic nerves have been displaced by the removal of the superficial muscles.

in number, arise from the nerve as it lies between the two heads of the Gastrocnemius muscle; they supply that muscle, and the Plantaris, Soleus, and Popliteus. The branch for the Popliteus turns round the lower border of that muscle, and is distributed to its deep surface. Lower down, muscular branches arise separately or by a common trunk and supply the Soleus, Tibialis posterior, Flexor digitorum longus, and Flexor hallucis longus; the branch to the last muscle accompanies the peronæal artery; that to the Soleus enters the deep surface of the muscle.

The *medial sural cutaneous nerve* (n. communicans tibialis) descends between the two heads of the Gastrocnemius on to the superficial surface of the muscle, and, about the middle of the back of the leg, pierces the deep fascia, and unites with the peronæal anastomotic branch of the common peronæal nerve to form the sural nerve (fig. 851). The *sural nerve* (external saphenous nerve) passes downwards near the lateral margin of the tendo calcaneus, lying close to the small saphenous vein, to the interval between the lateral malleolus and the calcaneus; it supplies the skin of the lateral and posterior part of the lower third of the leg. It then runs forwards below the lateral malleolus, and is continued as the *lateral dorsal cutaneous nerve* along the lateral side of the foot and little toe, communicating on the dorsum of the foot with the intermediate dorsal cutaneous nerve, a branch of the superficial peronæal nerve. In the leg, its branches communicate with those of the posterior femoral cutaneous nerve.

The *medial calcaneal branch* perforates the lacinate ligament, and supplies the skin of the heel and medial side of the sole of the foot.

The *medial plantar nerve* (fig. 854), the larger of the two terminal divisions of the tibial nerve, accompanies the medial plantar artery. From its origin under the lacinate ligament it passes under cover of the Abductor hallucis, and, appearing between this muscle and the Flexor digitorum brevis, gives off a proper digital plantar nerve to the medial side of the great toe and finally divides opposite the bases of the metatarsal bones into three common digital plantar nerves.

Branches.—*Cutaneous branches* pierce the plantar aponeurosis between the Abductor hallucis and the Flexor digitorum brevis and are distributed to the skin of the sole of the foot.

Muscular branches supply the Abductor hallucis, the Flexor digitorum brevis, the Flexor hallucis brevis, and the first Lumbricalis; those for the Abductor hallucis and Flexor digitorum brevis arise from the trunk of the nerve near its origin and enter the deep surfaces of the muscles; the branch for the Flexor hallucis brevis springs from the proper digital nerve to the medial side of the great toe, and that for the first Lumbricalis from the first common digital nerve.

Articular branches supply the articulations of the tarsus and metatarsus.

The *proper digital nerve of the great toe* supplies the Flexor hallucis brevis and the skin on the medial side of the great toe.

The *three common digital nerves* pass between the divisions of the plantar aponeurosis, and each splits into two proper digital nerves. Those of the first common digital nerve supply the adjacent sides of the great and second toes; those of the second, the adjacent sides of the second and third toes; and those of the third, the adjacent sides of the third and fourth toes. The third common digital nerve receives a communicating branch from the lateral plantar nerve; the first gives a twig to the first Lumbricalis. Each proper digital nerve gives off cutaneous and articular filaments, and opposite the last phalanx sends upwards a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. It will be observed that the digital nerves of the medial plantar nerve are similar in their distribution to those of the median nerve in the hand.

The *lateral plantar nerve* (fig. 854) supplies the skin of the fifth toe and lateral half of the fourth, as well as most of the deep muscles, its distribution being similar to that of the ulnar nerve in the hand. It passes obliquely forwards with the lateral plantar artery to the lateral side of the foot, lying between the Flexor digitorum brevis and Quadratus plantæ, and, in the interval between the former muscle and the Abductor digiti quinti, divides into a superficial and a deep branch. Before its division, it supplies the Quadratus plantæ and Abductor digiti quinti.

The *superficial branch* splits into a proper and a common digital nerve; the proper digital nerve supplies the lateral side of the little toe, the Flexor digiti quinti brevis, and the two Interossei of the fourth intermetatarsal space; the common digital nerve communicates with the third common digital branch of the medial plantar nerve and divides into two proper digital nerves which supply the adjoining sides of the fourth and fifth toes.

The *deep branch* accompanies the lateral plantar artery on the deep surface of the tendons of the flexor muscles and the Adductor hallucis, and supplies all the Interossei (except those in the fourth metatarsal space), the second, third, and fourth Lumbricales, and the Adductor hallucis.

FIG. 854.—The plantar nerves.

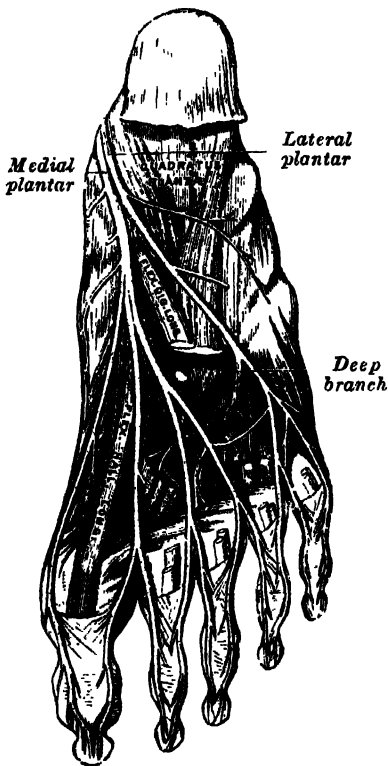
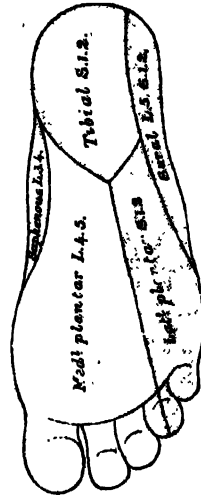


FIG. 855.—A diagram of the segmental distribution of the cutaneous nerves of the sole of the foot.



✓ The common peroneal nerve (external popliteal nerve) (fig. 853), about one-half the size of the tibial, is derived from the dorsal branches of the fourth and fifth lumbar and the first and second sacral nerves. It descends obliquely along the lateral side of the popliteal fossa to the head of the fibula, close to the medial margin of the Biceps femoris muscle. It lies between the tendon of the Biceps femoris and lateral head of the Gastrocnemius muscle, winds round the neck of the fibula, between the Peroneus longus and the bone, and divides beneath the muscle into the superficial and deep peroneal nerves. Previous to its division it gives off articular and lateral sural cutaneous nerves.

The *articular branches* are three in number; two of these accompany the superior and inferior lateral genicular arteries to the knee; the upper one occasionally arises from the trunk of the sciatic nerve. The third, named the recurrent articular nerve, is given off at the point of division of the common peroneal nerve; it ascends with the anterior recurrent tibial artery through the Tibialis anterior to the front of the knee.

The *lateral sural cutaneous nerve* supplies the skin on the posterior and lateral surfaces of the leg; one branch, the *peroneal anastomotic* (n. communicans fibularis), arises near the head of the fibula, crosses the lateral head

of the Gastrocnemius to the middle of the leg, and joins with the medial sural cutaneous to form the sural nerve (p. 923). The peronæal anastomotic nerve occasionally descends as a separate branch as far as the heel.

The deep peronæal nerve (anterior tibial nerve) (fig. 848) begins at the bifurcation of the common peronæal nerve, between the fibula and upper part of the Peronæus longus, passes obliquely forwards beneath the Extensor digitorum longus to the front of the interosseous membrane, and comes into relation with the anterior tibial artery in the upper third of the leg; it then descends with the artery to the front of the ankle-joint, where it divides into a lateral and a medial terminal branch. It lies at first on the lateral side of the anterior tibial artery, then in front of it, and again on its lateral side at the ankle-joint.

In the leg, the deep peronæal nerve supplies *muscular branches* to the Tibialis anterior, Extensor hallucis longus, Extensor digitorum longus and Peronæus tertius, and an *articular branch* to the ankle-joint.

The *lateral terminal branch* passes across the tarsus, beneath the Extensor digitorum brevis, and, having become enlarged like the dorsal interosseous nerve at the wrist, supplies the Extensor digitorum brevis. From the enlargement three minute *interosseous branches* are given off, which supply the tarsal joints, and the metatarsophalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second Interosseus dorsalis muscle.

The *medial terminal branch* accompanies the dorsalis pedis artery along the dorsum of the foot, and, at the first interosseous space, communicates with the medial dorsal cutaneous branch of the superficial peronæal nerve, and divides into two dorsal digital nerves, which supply the adjacent sides of the great and second toes. Before it divides it gives off an *interosseous branch* which supplies the metatarsophalangeal joint of the great toe and sends a filament to the first Interosseus dorsalis muscle.

The superficial peronæal nerve (musculocutaneous nerve) (fig. 848) begins at the bifurcation of the common peronæal nerve, passes forwards between the Peronæi and the Extensor digitorum longus, pierces the deep fascia at the lower third of the leg, and divides into a medial and an intermediate dorsal cutaneous nerve. In its course between the muscles, it gives off muscular branches to the Peronæus longus and Peronæus brevis, and filaments to the skin of the lower part of the leg.

The *medial dorsal cutaneous nerve* passes in front of the ankle-joint, and divides into two dorsal digital branches, one of which supplies the medial side of the great toe, the other, the adjacent sides of the second and third toes. It also supplies the skin of the medial side of the foot and ankle, and communicates with the saphenous nerve and with the deep peronæal nerve (fig. 846).

The *intermediate dorsal cutaneous nerve*, the smaller, passes along the lateral part of the dorsum of the foot, and divides into dorsal digital branches, which supply the contiguous sides of the third and fourth, and of the fourth and fifth toes. It also supplies the skin of the lateral side of the foot and ankle, and communicates with the lateral dorsal cutaneous nerve (fig. 846).

The branches of the superficial peronæal nerve supply the skin of the dorsal surfaces of all the toes excepting the lateral side of the little toe and the adjoining sides of the great and second toes, the former being supplied by the lateral dorsal cutaneous branch of the sural nerve, and the latter by the medial branch of the deep peronæal nerve. Frequently some of the lateral branches of the superficial peronæal are absent, and their places are then taken by branches of the lateral dorsal cutaneous nerve.

PUDENDAL PLEXUS

The pudendal plexus (fig. 849) is not sharply marked off from the sacral plexus, and as a consequence some of the branches which spring from it arise in conjunction with those of the sacral plexus. It lies on the posterior wall of the pelvic cavity, and is usually formed by branches from the anterior divisions of the second, third, and fourth sacral nerves, the whole of the anterior divisions of the fifth sacral nerve and the coccygeal nerve.

It gives off the following branches :

Perforating cutaneous	2, 3 S.
Pudendal	2, 3, 4 S. <i>h</i>
Visceral	3, 4 S.
Muscular	4 S.
Anococcygeal	4, 5 S. and Cocc.

The **perforating cutaneous nerve** usually arises from the posterior surfaces of the second and third sacral nerves. It pierces the lower part of the sacrotuberous ligament, and, winding round the inferior border of the Glutæus maximus, supplies the skin covering the medial and lower parts of that muscle.

The perforating cutaneous nerve may arise from the pudendal or it may be absent : in the latter case its place may be taken by a branch from the posterior femoral cutaneous nerve or by a branch from the third and fourth, or fourth and fifth, sacral nerves.

The **pudendal nerve** (pudic nerve) derives its fibres from the ventral branches of the second, third, and fourth sacral nerves. It passes between the Piriformis and Coccygeus muscles and leaves the pelvis through the lower part of the greater sciatic foramen. It then crosses the spine of the ischium on the medial side of the internal pudendal vessels, and passes through the lesser sciatic foramen. It accompanies the internal pudendal vessels upwards and forwards along the lateral wall of the ischiorectal fossa, being contained with them in a sheath of the obturator fascia termed *Alcock's canal* ; after giving off the inferior hæmorrhoidal nerve, it divides into the perineal nerve, and the dorsal nerve of the penis or clitoris.

The *inferior hæmorrhoidal nerve* occasionally arises directly from the sacral plexus ; it crosses the ischiorectal fossa with the inferior hæmorrhoidal vessels, towards the anal canal and the lower end of the rectum, and is distributed to the Sphincter ani externus and to the skin round the anus. Branches of this nerve communicate with the perineal branch of the posterior femoral cutaneous and with the posterior scrotal nerves.

The *perineal nerve*, the inferior and larger terminal branch of the pudendal nerve, is situated below the internal pudendal artery. It accompanies the perineal artery and divides into posterior scrotal (or labial) and muscular branches.

The *posterior scrotal branches* (superficial perineal nerves) are two, a medial and a lateral. They pierce, or pass superficial to, the fascia of the urogenital diaphragm, and run forwards along the lateral part of the urethral triangle in company with the posterior scrotal branches of the perineal artery ; they are distributed to the skin of the scrotum, and communicate with the perineal branch of the posterior femoral cutaneous nerve. In the female the corresponding nerves (*posterior labial branches*) supply the *labium majus*.

The muscular branches are distributed to the *Transversus perinæi superficialis*, *Bulbocavernosus*, *Ischiocavernosus*, *Transversus perinæi profundus*, and *Sphincter urethræ membranaceæ*. A branch, the *nerve to the urethral bulb*, is given off from the nerve to the *Bulbocavernosus* ; it pierces this muscle, and supplies the *corpus cavernosum urethræ*, ending in the mucous membrane of the urethra.

The *dorsal nerve of the penis* is the deepest division of the pudendal nerve ; it accompanies the internal pudendal artery along the ramus of the ischium ; it then runs forwards along the margin of the inferior ramus of the os pubis, between the superior and inferior layers of the fascia of the urogenital diaphragm. Piercing the inferior layer it gives a branch to the *corpus cavernosum penis*, and passes forwards, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, on to the dorsum of the penis, and ends on the *glans penis*. In the female the corresponding nerve (*dorsal nerve of the clitoris*) is very small, and supplies the clitoris.

The *visceral branches* arise from the third and fourth, and sometimes from the second, sacral nerves, and are distributed to the bladder and rectum and, in the female, to the vagina ; they communicate with the pelvic plexuses of the sympathetic.

The *muscular branches* are derived from the fourth sacral, and supply the *Levator ani*, *Coccygeus*, and *Sphincter ani externus*. The branches to the

Levator ani and *Coccygeus* enter their pelvic surfaces; that to the *Sphincter ani externus* (perineal branch of fourth sacral nerve) reaches the ischio-rectal fossa by piercing the *Coccygeus* or by passing between it and the *Levator ani*. Cutaneous filaments from this branch supply the skin between the anus and the coccyx.

Anococcygeal nerves.—The anterior division of the fifth sacral nerve receives a communicating filament from the fourth, and unites with the minute anterior division of the coccygeal nerve to form the *coccygeal plexus*. From this plexus the anococcygeal nerves take origin; they consist of a few fine filaments which pierce the sacrotuberous ligament and supply the skin in the region of the coccyx.

Applied Anatomy.—The lumbar plexus passes through the *Psoas major*, and therefore in *psoas abscess* any or all of its branches may be irritated, causing severe pain in the part to which the irritated nerves are distributed. The genitofemoral nerve is the one which is most frequently implicated. This nerve is also of importance as it is concerned in one of the principal superficial reflexes employed in the investigation of diseases of the medulla spinalis. If the skin over the medial side of the thigh just below the inguinal ligament (the part supplied by the lumbo-inguinal branch of the genitofemoral nerve) be tickled in the male child, the testis will be retracted, through the action of the *Cremaster* muscle which is supplied by the external spermatic branch of the genitofemoral nerve. The same result may sometimes be noticed in adults, and can almost always be produced by severe stimulation. This reflex shows that the portion of the medulla spinalis from which the first and second lumbar nerves are derived is in a normal condition.

The femoral nerve is in danger of being injured in fractures of the lesser pelvis, since the fracture most commonly takes place through the superior ramus of the os pubis, at or near the point where this nerve crosses the bone. It is also liable to be pressed upon and its functions impaired, by some tumours growing in the pelvis. Moreover, on account of its superficial position, it is exposed to injury in wounds and stabs in the groin. Its central origin is often affected in cases of infantile paralysis. When this nerve is paralysed, the patient is unable to flex his hip completely, on account of the paralysis of the *Iliacus*; or to extend the knee on the thigh, on account of paralysis of the *Quadriceps femoris*; there is complete paralysis of the *Sartorius*, and partial paralysis of the *Pectineus*. There is loss of sensation down the front and medial side of the thigh, except in that part supplied by the lumbo-inguinal and ilio-inguinal nerves. There is also loss of sensation down the medial side of the leg and foot as far as the ball of the great toe.

The obturator nerve is rarely paralysed alone, but occasionally in association with the femoral. The principal interest attached to it is in connexion with its supply to the knee, pain in the knee being symptomatic of many diseases in which the trunk of this nerve, or one of its branches, is irritated. Thus it is well known that in the earlier stages of hip-joint disease the patient may not always complain of pain in that articulation, but on the medial side of the knee, or in the knee-joint itself, both of these articulations being supplied by the obturator nerve, the final distribution of the nerve being to the knee-joint. Again, the same thing may occur in sacro-iliac disease; or in cases of pathological growth of the ovary or tubal inflammation; or in cancer of the sigmoid colon; and even in cases where masses of hardened faeces are impacted in this portion of the gut, pain is complained of in the knee. Finally, pain in the knee forms an important diagnostic sign in obturator hernia. When the obturator nerve is paralysed, the patient is unable to press his knees together or to cross one leg over the other, on account of paralysis of the *Adductor* muscles. Rotation outwards of the thigh is impaired from paralysis of the *Obturator externus*. Sometimes there is loss of sensation in the upper half of the medial side of the leg.

The sciatic nerve is liable to be pressed upon by various forms of pelvic tumour, giving rise to pain along its trunk, to which the term *sciatica* is applied. Tumours growing from the pelvic viscera, especially advanced cancer of the rectum, aneurysms of some of the branches of the hypogastric artery, calculus in the bladder when of large size, accumulation of faeces in the rectum, may all cause pressure on the nerve inside the pelvis, and give rise to sciatica. Outside the pelvis, exostoses or other tumours growing from the margin of the greater sciatic foramen may also give rise to the same condition. Most cases of sciatica, however, are due to neuritis of the sciatic nerve from exposure to cold, and it occurs more often in men, in the latter half of life, and often in association with rheumatism, gout, or diabetes mellitus. The inflamed nerve is often sensitive to pressure, particularly in certain 'tender spots' (e.g. near the posterior iliac spine, at the sciatic notch, about the middle of the back of the thigh, in the popliteal fossa, below the head of the fibula, behind the malleoli, or on the dorsum of the foot), and pain is felt whenever extension of the leg is attempted and the nerve is stretched. Paralysis of the sciatic nerve is rarely complete; when the lesion occurs high up there is palsy of the *Biceps femoris*, *Semimembranosus*, and *Semitendinosus*, and of all the muscles below the knee. If the lesion be lower down, there is loss of motion in all the muscles below the knee, and loss of sensation in the same situation, except the upper half of the back of the leg, which is supplied by the posterior femoral cutaneous, and in the upper half of the medial

side of the leg, when the communicating branch of the obturator is large (p. 915). Lesions of the common peroneal nerve cause paralysis of the *Tibialis anterior*, the *Peronæi*, the long Extensors of the toes, and the short Extensor on the dorsum of the foot. 'Foot-drop' follows, dorsal flexion of the toes and abduction of the foot being impossible. Later on, talipes of the equinovarus type results, due to the contracture of the unopposed posterior crural group of muscles.

The sciatic nerve has been frequently cut down upon and stretched, or has been acupunctured, for the relief of sciatica. In order to define it on the surface, a point is taken at the junction of the middle and lower thirds of a line stretching from the posterior superior spine of the ilium to the lateral part of the ischial tuberosity, and a line drawn from this to the middle of the upper part of the popliteal fossa. The line must be slightly curved with its convexity outwards, and, as it passes downwards to the lower border of the *Glutæus maximus*, is slightly nearer to the ischial tuberosity than to the greater trochanter, as it crosses a line drawn between these two points. The operation of stretching the sciatic nerve is performed by making an incision over the course of the nerve beneath the fold of the buttock. The skin, superficial structures, and deep fascia having been divided, the hamstrings are defined, and pulled apart with retractors. The nerve will be found lying on the Adductor magnus and covered by the Biceps femoris. It is to be separated from the surrounding structures, hooked up with the finger, and stretched by steady and continuous traction for two or three minutes. The sciatic nerve may also be stretched by what is known as the 'dry' plan. The patient is laid on his back, the foot is extended, the leg flexed on the thigh, and the thigh strongly flexed on the abdomen. While the thigh is maintained in this position, the leg is forcibly extended to its full extent, and the foot as fully flexed on the leg.

The position of the common peroneal nerve, close behind the tendon of the Biceps femoris, on the lateral side of the popliteal fossa, should be remembered in subcutaneous division of the tendon. After the tendon is divided, the common peroneal nerve rises up as a cord, and might be mistaken for a small undivided portion of the tendon. Where this nerve winds round the neck of the fibula, it is also liable to be severed accidentally if its exact situation is not kept in mind, and especial care must be used when dealing with sinuses leading down to carious bone in this situation. Section of the nerve results in complete 'foot-drop' from paralysis of the anterior tibial group of muscles and inversion of the foot from the unopposed action of the *Tibialis posterior*, the *Peronæi* being paralysed, together with anesthesia of the parts supplied by the nerve, and, owing to loss of nutrition, the limb frequently becomes blue and cold, and may develop 'trophic' sores.

THE SYMPATHETIC NERVOUS SYSTEM

The sympathetic nerves are distributed to the viscera, glands and blood-vessels, and to unstriated muscle in general. They are characterised by the presence of numerous ganglia which may be divided into central, collateral and terminal groups.

The *central* ganglia are arranged in two vertical rows, one on either side of the middle line, and situated partly in front and partly at the sides of the vertebral column. The ganglia of each row are joined by intervening nervous cords, so that two trunks, named the *sympathetic trunks*, are formed. The *collateral* ganglia are found in connexion with three great *prevertebral plexuses* placed within the thorax, abdomen and pelvis and named respectively the *cardiac*, *celiac* and *hypogastric* plexuses. The *terminal* ganglia are located in the walls of the viscera.*

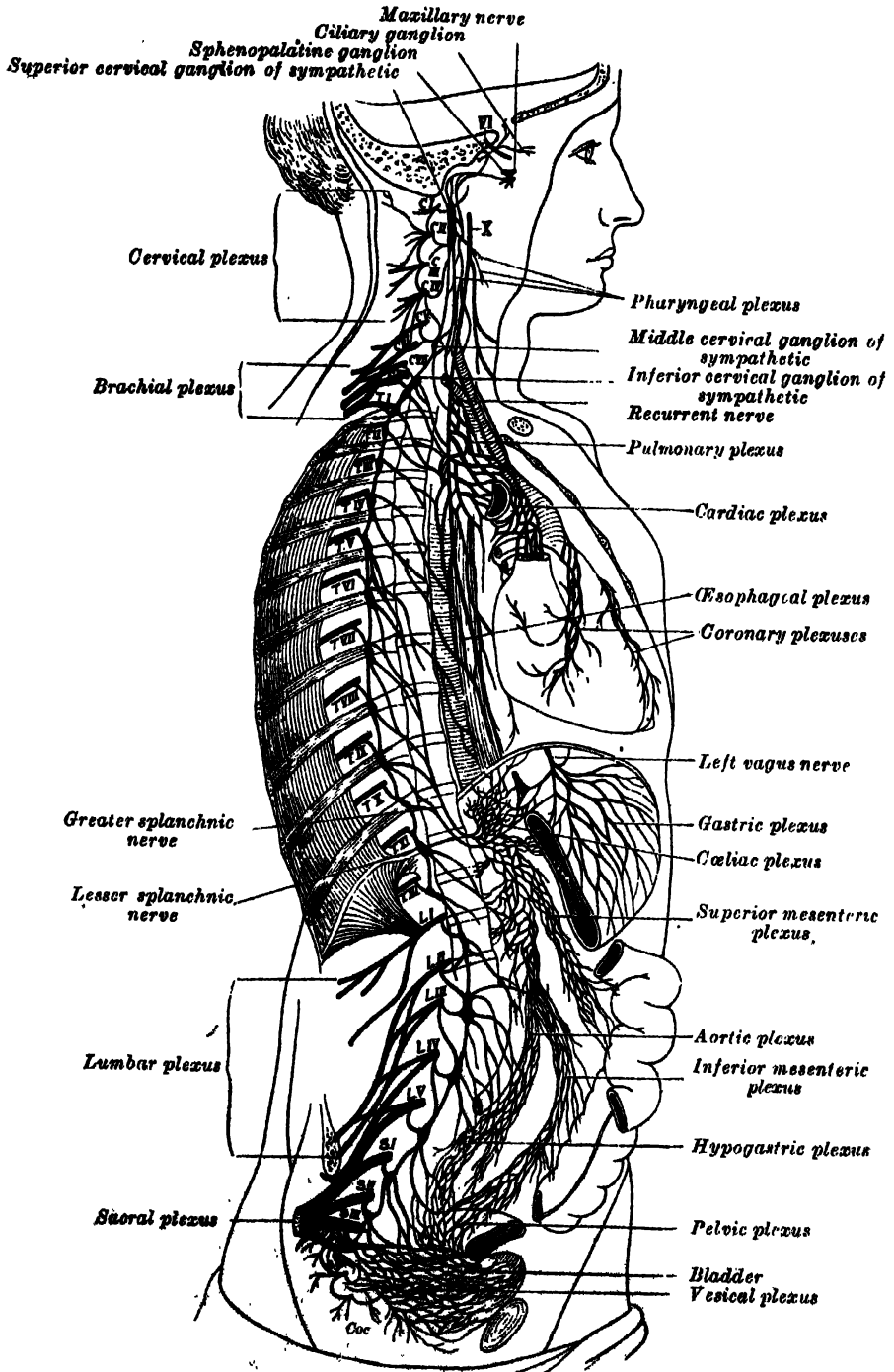
The efferent fibres of the sympathetic nerves originate as *preganglionic* fibres (p. 740) which are the axons of cells in the lateral grey column of the medulla spinalis. These fibres, medullated and mostly of small size, leave the medulla spinalis through the anterior nerve-roots of the spinal nerves in a thoracolumbar and a sacral group.

The *thoracolumbar* group of preganglionic fibres issue through the thoracic and the first and second lumbar nerves, and, leaving those nerves in the *white rami communicantes*, join the sympathetic trunks. Some of them end by forming synapses around the cells of the central ganglia of the sympathetic trunks. Others, after ascending or descending through the sympathetic trunks for varying distances, leave them and terminate in synapses around

*The ciliary, sphenopalatine, otic, and submaxillary ganglia, already described with the trigeminal nerve, form part of the autonomic system, and are closely allied to the sympathetic (p. 741).

the cells of the collateral ganglia in the prevertebral plexuses, or around the cells of the terminal ganglia in the walls of the viscera. All the preganglionic

FIG. 856.—The right sympathetic trunk and its connexions with the thoracic, abdominal, and pelvic plexuses. (After Schwalbe.)

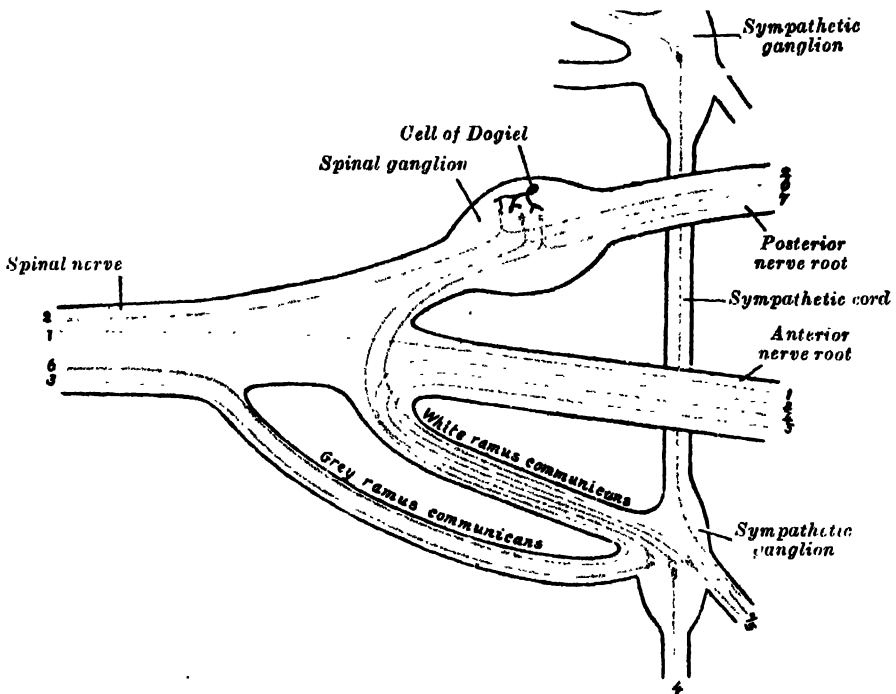


fibres end by forming synapses around cells in the central, collateral or terminal sympathetic ganglia.

From the cells of the sympathetic ganglia fibres, mostly non-medullated, arise. Some of these fibres go directly, or through the prevertebral plexuses, to their distribution in the viscera, while others leave the sympathetic trunks in the *grey rami communicantes* and join the spinal nerves, through which they are conveyed to the blood-vessels, sudoriferous glands and Arrectores pilorum muscles.

The *sacral* group of preganglionic fibres emerge in the second, third and fourth sacral nerves and constitute the *pelvic splanchnic nerves* of Gaskell. They do not join the sympathetic trunks, but pass directly into the pelvic plexuses of the sympathetic; from the cells of these plexuses postganglionic fibres take origin and are distributed to the viscera of the pelvis.

FIG. 857.—A scheme showing the structure of a typical spinal nerve.



1. Somatic efferent. 2. Somatic afferent. 3, 4. Sympathetic efferent. 6, 7. Sympathetic afferent.

As already stated (p. 741) certain fine medullated fibres, homologous with the preganglionic fibres from the medulla spinalis, issue from the oculomotor, facial, glossopharyngeal, vagus and accessory cerebral nerves, and pass to peripherally placed ganglia. These fibres, together with those of the sympathetic system, constitute the *autonomic system*.

The afferent fibres of the sympathetic nerves originate in the cells of the spinal ganglia. The peripheral processes of these cells run in the white rami communicantes, and, after passing through one or more sympathetic ganglia (but always without interruption in them) end in the viscera, etc. The central processes enter the medulla spinalis through the posterior nerve-roots and form synapses around either somatic or sympathetic neurons.

The sympathetic trunks extend from the base of the skull to the coccyx. The superior extremity of each trunk is continued upwards under the name of the internal carotid nerve, through the carotid canal into the skull. Here it forms the carotid and cavernous plexuses which constitute the *cephalic part* of the sympathetic system. The inferior extremities of the sympathetic trunks converge and unite in a single ganglion, the *ganglion impar*, which is

placed in front of the coccyx. The ganglia of each trunk are distinguished as cervical, thoracic, lumbar, and sacral, and, except in the neck, their number corresponds more or less closely to that of the vertebræ. They are arranged thus :

Cervical portion	.	.	.	3 ganglia
Thoracic	„	.	.	12 „
Lumbar	„	.	.	4 „
Sacral	„	.	.	4 or 5 „

In the neck the ganglia lie in front of the transverse processes of the vertebræ; in the thoracic region in front of the heads of the ribs; in the lumbar region on the sides of the vertebral bodies; and in the sacral region in front of the sacrum.

CEPHALIC PORTION OF THE SYMPATHETIC SYSTEM

The cephalic portion of the sympathetic system on each side begins as the *internal carotid nerve*, which is continued upwards from the superior cervical ganglion of the sympathetic trunk. This nerve is soft in texture, and of a reddish colour. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, one of which lies on the lateral and the other on the medial side of the artery.

The *lateral branch*, the larger of the two, gives filaments to the internal carotid artery, and forms the *internal carotid plexus*.

The *medial branch* also supplies filaments to the internal carotid artery, and, continuing onwards, forms the *cavernous plexus*.

The *internal carotid plexus* is situated on the lateral side of the internal carotid artery, and in the plexus there occasionally exists a small gangliform swelling, the *carotid ganglion*, on the under surface of the artery. The plexus communicates with the semilunar and sphenopalatine ganglia, and with the abducent nerve and the tympanic branch of the glossopharyngeal nerve; it distributes filaments to the wall of the carotid artery.

The branches communicating with the abducent nerve consist of one or two filaments which join that nerve as it lies upon the lateral side of the internal carotid artery. The communication with the sphenopalatine ganglion is effected by a branch named the *deep petrosal*; this branch passes through the cartilage filling the foramen lacerum, and joins the greater superficial petrosal nerve to form the nerve of the pterygoid canal (Vidian nerve), which passes through the pterygoid canal to the sphenopalatine ganglion. The communication with the tympanic branch of the glossopharyngeal nerve is effected by the *superior and inferior carotidotympanic nerves* which traverse the wall of the carotid canal.

The *cavernous plexus*, formed chiefly by the medial division of the internal carotid nerve, is situated below and on the medial side of that part of the internal carotid artery which is placed by the side of the sella turcica, in the cavernous sinus. It gives branches to the internal carotid artery, and communicates with the oculomotor, trochlear, ophthalmic, and abducent nerves, and with the ciliary ganglion.

The branch to the oculomotor nerve joins that nerve at its point of division; the branch to the trochlear nerve joins the latter as it lies in the lateral wall of the cavernous sinus; filaments are connected with the medial side of the ophthalmic nerve; and one joins the abducent nerve. The filament to the ciliary ganglion arises from the anterior part of the cavernous plexus and enters the orbit through the superior orbital fissure; it may join the ganglion directly, or may unite with the long root of the ganglion.

The terminal filaments from the internal carotid and cavernous plexuses are prolonged as plexuses around the anterior and middle cerebral arteries and the ophthalmic artery: along the anterior and middle cerebral arteries they may be traced to the pia mater; along the ophthalmic artery into the orbit where they accompany each of the branches of that vessel. The filaments prolonged on to the anterior communicating artery connect the sympathetic nerves of the right and left sides.

CERVICAL PORTION OF THE SYMPATHETIC SYSTEM

The cervical portion of each sympathetic trunk consists of three ganglia, distinguished, according to their positions, as the superior, middle, and inferior, connected by intervening cords. This portion receives no white rami communicantes from the cervical spinal nerves; its spinal fibres are derived from the white rami of the upper thoracic nerves, and enter the corresponding thoracic ganglia of the sympathetic trunk, through which they ascend into the neck.

The superior cervical ganglion, the largest of the three, is placed opposite the second and third cervical vertebrae. It is of a reddish-grey colour, and usually fusiform in shape, sometimes broad and flattened, and occasionally constricted at intervals; it is believed to be formed by the coalescence of four ganglia, corresponding to the upper four cervical nerves. It is in relation, in front, with the sheath of the internal carotid artery and internal jugular vein; behind, with the Longus capitis muscle. The internal carotid nerve (p. 931) ascends from the upper end of the ganglion into the cranial cavity; the lower end of the ganglion is united by the connecting trunk with the middle cervical ganglion.

Its branches may be divided into lateral, medial, and anterior.

The lateral branches consist of grey rami communicantes to the upper four cervical nerves and to certain of the cerebral nerves. Sometimes the branch to the fourth cervical nerve may come from the trunk connecting the upper and middle cervical ganglia. Delicate filaments run to the ganglion nodosum of the vagus, and to the hypoglossal nerve, and a branch, named the *jugular nerve*, ascends to the base of the skull, and divides into two twigs, one of which joins the petrous ganglion of the glossopharyngeal, and the other the jugular ganglion of the vagus.

The medial branches are the laryngopharyngeal branches and the superior cardiac nerve.

The *laryngopharyngeal branches* pass to the side of the pharynx, where they join with branches from the glossopharyngeal and vagus nerves to form the *pharyngeal plexus*. From this plexus branches pass to the muscles and mucous membrane of the pharynx, and communicate with the superior laryngeal nerve.

The *superior cardiac nerve* arises by two or more branches from the superior cervical ganglion, and occasionally receives a filament from the trunk between the superior and middle cervical ganglia. It runs down the neck behind the common carotid artery, and in front of the Longus colli muscle; and crosses in front of the inferior thyroid artery, and recurrent nerve. The course of the nerve of the right side then differs from that of the left. The *right nerve*, at the root of the neck, passes either in front of or behind the subclavian artery, and along the innominate artery to the back of the arch of the aorta, where it joins the deep part of the cardiac plexus. It is connected with other branches of the sympathetic; about the middle of the neck it receives filaments from the external laryngeal nerve; lower down, one or two twigs (upper cervical branches) from the vagus; and as it enters the thorax it is joined by a filament from the recurrent nerve. Filaments from the nerve communicate with the thyroid branches from the middle cervical ganglion. The *left nerve*, in the thorax, runs in front of the left common carotid artery and across the left side of the arch of the aorta, to the superficial part of the cardiac plexus. Sometimes it descends on the right side of the aorta and ends in the deep part of the cardiac plexus.

The anterior branches ramify upon the common carotid artery and upon the external carotid artery and its branches, forming round each a delicate plexus in which small ganglia are occasionally found. The plexus surrounding the external maxillary artery supplies a filament to the submaxillary ganglion, and the plexus on the middle meningeal artery sends one offset to the otic ganglion, and another, the *external petrosal nerve*, to the genicular ganglion of the facial nerve.

The middle cervical ganglion is the smallest of the three cervical ganglia, and is occasionally wanting. It is placed opposite the sixth cervical vertebra, usually in front of, or close to, the inferior thyroid artery. It is probably

formed by the coalescence of two ganglia corresponding with the fifth and sixth cervical nerves.

It sends grey rami communicantes to the fifth and sixth cervical nerves, and gives off thyreoid branches, and the middle cardiac nerve.

The *thyreoid branches* run along the inferior thyreoid artery to the thyreoid gland; they communicate with the superior cardiac, external laryngeal and recurrent nerves.

The *middle cardiac nerve*, the largest of the three cardiac nerves, arises from the middle cervical ganglion, or from the trunk between the middle and inferior ganglia. On the *right side* it descends behind the common carotid artery, and at the root of the neck runs either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent nerve, and joins the right half of the deep part of the cardiac plexus. In the neck, it communicates with the superior cardiac and recurrent nerves. On the *left side*, the middle cardiac nerve enters the thorax between the left carotid and subclavian arteries, and joins the left half of the deep part of the cardiac plexus.

The *inferior cervical ganglion* is situated between the base of the transverse process of the last cervical vertebra and the neck of the first rib, on the medial side of the costocervical trunk. Its form is irregular; it is larger in size than the preceding, and is frequently fused with the first thoracic ganglion. It is probably formed by the coalescence of two ganglia which correspond to the seventh and eighth cervical nerves. It is connected to the middle cervical ganglion by two or more cords, one of which forms a loop around the subclavian artery, and supplies offsets to it. This loop is named the *ansa subclavia* (*Vieussensii*).

The ganglion sends grey rami communicantes to the seventh and eighth cervical nerves, gives off the inferior cardiac nerve, and supplies branches to blood-vessels.

The *inferior cardiac nerve* arises from either the inferior cervical or the first thoracic ganglion. It descends behind the subclavian artery and along the front of the trachea, to join the deep part of the cardiac plexus. Behind the subclavian artery it communicates with the recurrent and middle cardiac nerves.

The *offsets to blood-vessels* form plexuses on the subclavian artery and its branches. The plexus on the vertebral artery is continued on to the basilar, posterior cerebral, and cerebellar arteries. The plexus on the inferior thyreoid artery accompanies the artery to the thyreoid gland, and communicates with the recurrent and external laryngeal nerves, with the superior cardiac nerve, and with the plexus on the common carotid artery.

THORACIC PORTION OF THE SYMPATHETIC SYSTEM (fig. 858)

The thoracic portion of the sympathetic trunk consists on either side of a series of ganglia, which usually correspond in number to that of the vertebræ; but, on account of the occasional coalescence of two ganglia, their number is variable. The thoracic ganglia, with the exception of the last two, rest against the heads of the ribs, and are covered by the costal pleura; the last two are placed on the sides of the bodies of the eleventh and twelfth thoracic vertebræ. The ganglia are small, and of a greyish colour. The first is larger than the others, and of an elongated form; it is frequently blended with the inferior cervical ganglion. The ganglia are connected together by the intervening portions of the trunk.

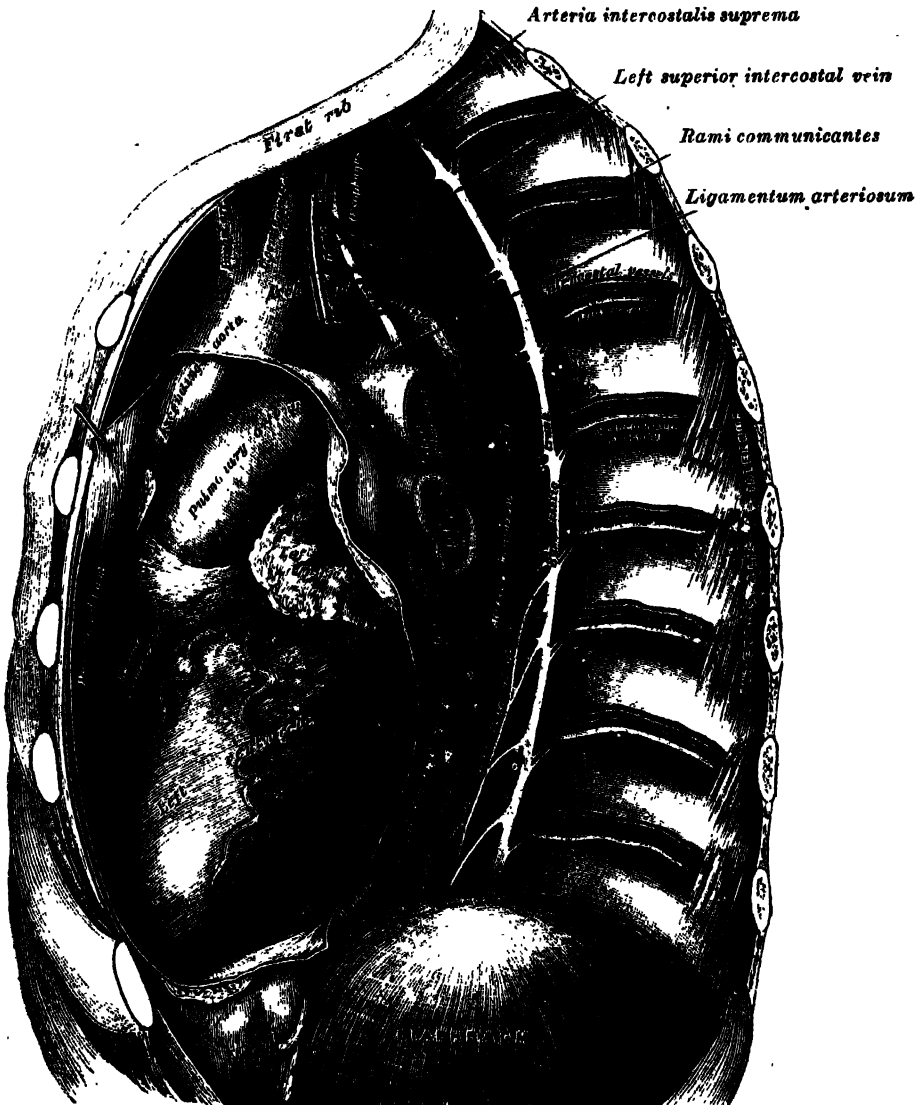
Two rami communicantes, a white and a grey, connect each ganglion with its corresponding spinal nerve.

The *branches from the upper five ganglia* are very small; they supply filaments to the thoracic aorta and its branches. On the aorta they form, together with filaments from the great splanchnic nerve, a delicate plexus (*plexus aorticus thoracalis*). Twigs from the second, third, and fourth ganglia enter the posterior pulmonary plexus.

The *branches from the lower seven ganglia* are large, and white in colour; they distribute filaments to the aorta, and unite to form the greater, the lesser, and the lowest splanchnic nerves.

The *greater splanchnic nerve* is of a considerable size, and consists mainly of medullated fibres; it is formed by branches from the fifth to the ninth or tenth thoracic ganglia, but the fibres in the higher roots may be traced upwards in the sympathetic trunk as far as the first or second thoracic ganglion. It descends obliquely on the bodies of the vertebræ, perforates the crus of the Diaphragm, and ends in the celiac ganglion. A ganglion (*ganglion splanchnicum*) exists on this nerve opposite the eleventh or twelfth thoracic vertebra.

FIG. 858.—The thoracic portion of the left sympathetic trunk.



The *lesser splanchnic nerve* is formed by filaments from the ninth and tenth, sometimes the tenth and eleventh, thoracic ganglia, and from the trunk between the ganglia. It pierces the Diaphragm with the preceding nerve, and joins the aorticorenal ganglion.

The *lowest splanchnic nerve* arises from the last thoracic ganglion. It pierces the Diaphragm with the sympathetic trunk, and ends in the renal plexus.

A striking analogy exists between the splanchnic and the cardiac nerves. The cardiac nerves are three in number; they arise from the cervical ganglia,

and are distributed to a large and important organ in the thoracic cavity. The splanchnic nerves, also three in number, arise from the thoracic ganglia, and are distributed to organs in the abdominal cavity.

ABDOMINAL PORTION OF THE SYMPATHETIC SYSTEM (fig. 859)

The abdominal portion of each sympathetic trunk is situated in front of the vertebral column, along the medial margin of the Psoas major. It consists usually of four lumbar ganglia, connected together by interganglionic cords. It is continuous above with the thoracic portion, beneath the medial lumbocostal arch; below with the pelvic portion, behind the common iliac artery.

Grey rami communicantes pass from all the ganglia to the lumbar spinal nerves. The first and second, and sometimes the third, lumbar nerves send white rami communicantes to the corresponding ganglia. The rami communicantes are of considerable length, and accompany the lumbar arteries around the sides of the bodies of the vertebrae, passing beneath the fibrous arches which give origin to some of the fibres of the Psoas major.

Of the *branches of distribution*, some pass in front of the aorta, and join the abdominal aortic plexus; others descend in front of the common iliac arteries, and assist in forming the hypogastric plexus.

PELVIC PORTION OF THE SYMPATHETIC SYSTEM (fig. 856)

The pelvic portion of each sympathetic trunk is situated in front of the sacrum, medially to the anterior sacral foramina. It consists of four or five small sacral ganglia, connected together by interganglionic cords, and continuous above with the abdominal portion. Below, the two pelvic sympathetic trunks converge, and unite on the front of the coccyx in a small ganglion, the *ganglion impar* or *coccygeal ganglion*.

Grey rami communicantes pass from the ganglia to the sacral and coccygeal nerves. No white rami communicantes are given to this part of the gangliated cord, but the visceral branches which arise from the second, third and fourth sacral nerves, and run directly to the pelvic plexuses, are regarded as white rami communicantes.

The *branches of distribution* communicate on the front of the sacrum with the corresponding branches from the opposite side; twigs from the first two ganglia join the pelvic plexus, and others form a plexus on the middle sacral artery. Filaments are distributed to the glomus coccygeum (coccygeal body) from the loop uniting the two trunks.

The following facts concerning the course of the sympathetic nerve-fibres have been arrived at by experiments on lower animals, chiefly dogs, but they probably hold good for the human sympathetic system:—

The sympathetic fibres for the head and neck leave the medulla spinalis through the upper five thoracic nerves (chiefly through the second and third nerves). They ascend in the cervical part of the sympathetic trunk and end in the superior cervical ganglion. The fibres arising from the cells of this ganglion are vasoconstrictor for the blood-vessels, secretory for the salivary and sudoriferous glands, and dilator for the pupil.

The accelerator fibres of the heart leave mainly through the second and third thoracic nerves and pass to the *stellate ganglion*. From the cells of this ganglion fibres are distributed to the heart.

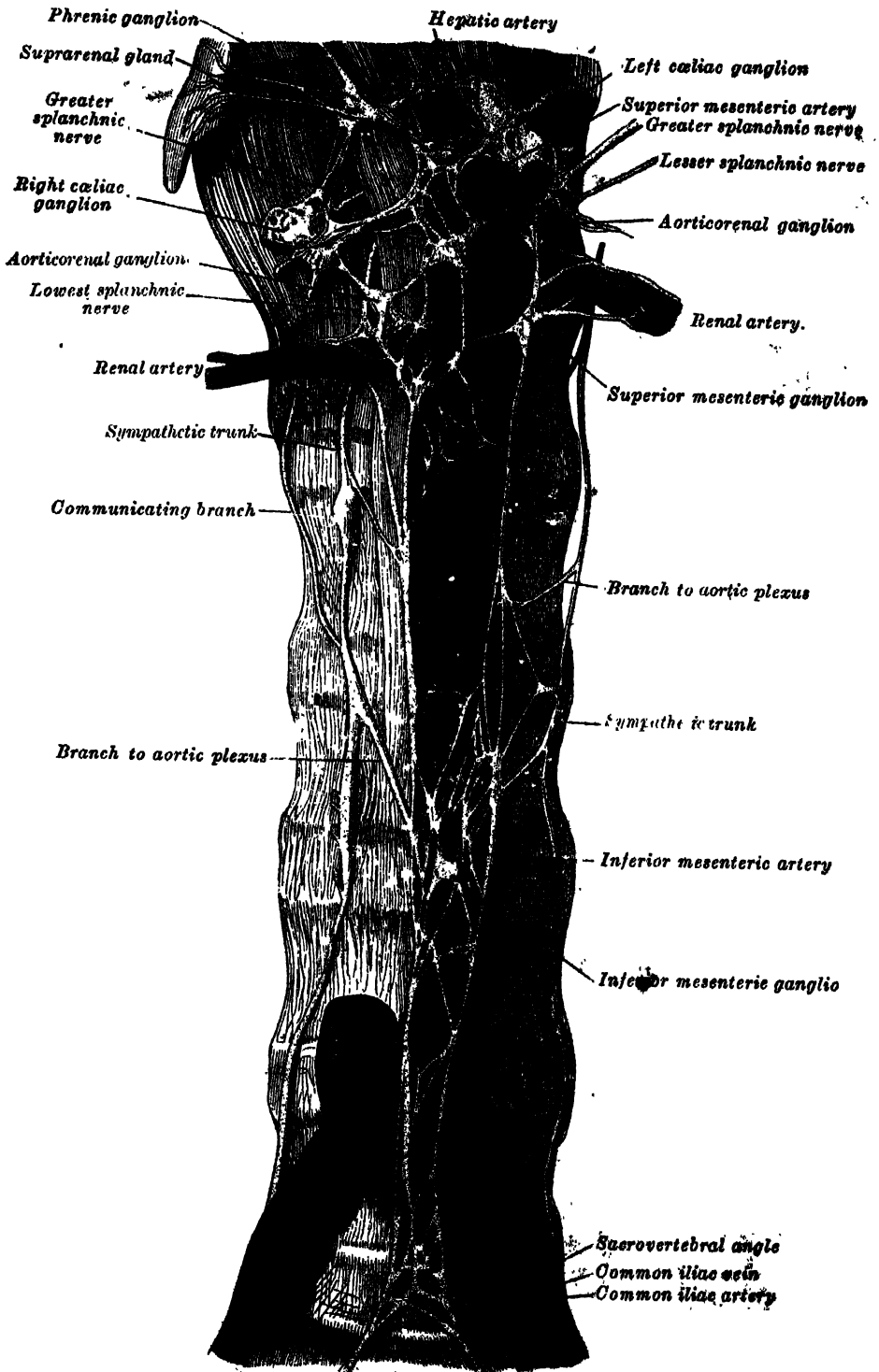
Fibres leave the thoracic spinal nerves (mainly the lower six) and are conveyed through the splanchnic nerves to the celiac ganglion, from the cells of which fibres pass to the blood-vessels and viscera of the abdominal cavity. Fibres from the lower thoracic and upper three or four lumbar nerves pass through the ganglia of the lumbar part of the sympathetic trunk to the inferior mesenteric ganglion; from this ganglion fibres are conveyed through the hypogastric and pelvic plexuses to the pelvic viscera.

No spinal fibres pass from the sacral nerves to the sympathetic trunks, but the visceral branches of the second, third and fourth sacral nerves correspond to white rami communicantes and enter the pelvic sympathetic plexuses. From these plexuses fibres are conveyed to the pelvic viscera, and vasodilator fibres (*nervi erigentes*) to the penis.

The constrictor fibres for the blood-vessels of the upper limbs leave the thoracic nerves from about the fourth to the tenth inclusive; those for the lower limbs through the lower two or three thoracic and upper three lumbar nerves.

* In the dog the upper four thoracic ganglia of the sympathetic trunk are fused into one mass which is named the *stellate ganglion*.

FIG. 859.—The abdominal portion of the sympathetic trunks, with the coeliac and hypogastric plexuses. (After Henle.)



THE GREAT PLEXUSES OF THE SYMPATHETIC

The great plexuses of the sympathetic are aggregations of nerves and ganglia, situated in the thoracic, abdominal, and pelvic cavities, and named the cardiac, coeliac, and hypogastric plexuses. They consist not only of sympathetic fibres derived from the ganglia, but of fibres from the medulla spinalis, which are conveyed through the white rami communicantes. From the plexuses branches are given to the thoracic, abdominal, and pelvic viscera.

CARDIAC PLEXUS (fig. 856)

The cardiac plexus is situated at the base of the heart, and is divided into a *superficial* and a *deep part*, which are, however, closely connected.

The *superficial part* of the cardiac plexus lies beneath the arch of the aorta, in front of the right pulmonary artery. It is formed by the superior cardiac branch of the left sympathetic trunk and the lower of the superior cardiac branches of the left vagus. A small ganglion, the *cardiac ganglion of Wisberg*, is occasionally found connected with these nerves at their point of junction; when present it is situated immediately beneath the arch of the aorta, on the right side of the ligamentum arteriosum. The superficial part of the cardiac plexus gives branches (a) to the deep part of the plexus; (b) to the anterior coronary plexus; and (c) to the left anterior pulmonary plexus.

The *deep part* of the cardiac plexus is situated in front of the bifurcation of the trachea, above the point of division of the pulmonary artery, and behind the aortic arch. It is formed by the cardiac nerves derived from the cervical ganglia of the sympathetic trunk, and the cardiac branches of the vagus and recurrent nerves. The only cardiac nerves which do not join the deep part of the cardiac plexus are the superior cardiac nerve of the left sympathetic trunk, and the lower of the superior cardiac branches from the left vagus nerve, which pass to the superficial part of the plexus.

The branches from the *right half* of the deep part of the cardiac plexus pass, some in front of, and others behind, the right pulmonary artery; the former, the more numerous, transmit a few filaments to the anterior pulmonary plexus, and are then continued onwards to form part of the anterior coronary plexus; those behind the pulmonary artery distribute a few filaments to the right atrium, and are then continued onwards to form part of the posterior coronary plexus.

The *left half* of the deep part of the plexus is connected with the superficial part of the cardiac plexus, and gives filaments to the left atrium, and to the anterior pulmonary plexus, and is then continued to form the greater part of the posterior coronary plexus.

The *posterior coronary plexus* is larger than the anterior, and accompanies the left coronary artery; it is formed chiefly by filaments prolonged from the left half of the deep part of the cardiac plexus, and by a few from the right half. It gives branches to the left atrium and ventricle.

The *anterior coronary plexus* is formed partly from the superficial and partly from the deep parts of the cardiac plexus. It accompanies the right coronary artery, and gives branches to the right atrium and ventricle.

The upper cardiac nerves are distributed to the ascending aorta, the pulmonary artery and the ventricles; the lower cardiac nerves, to the atria.

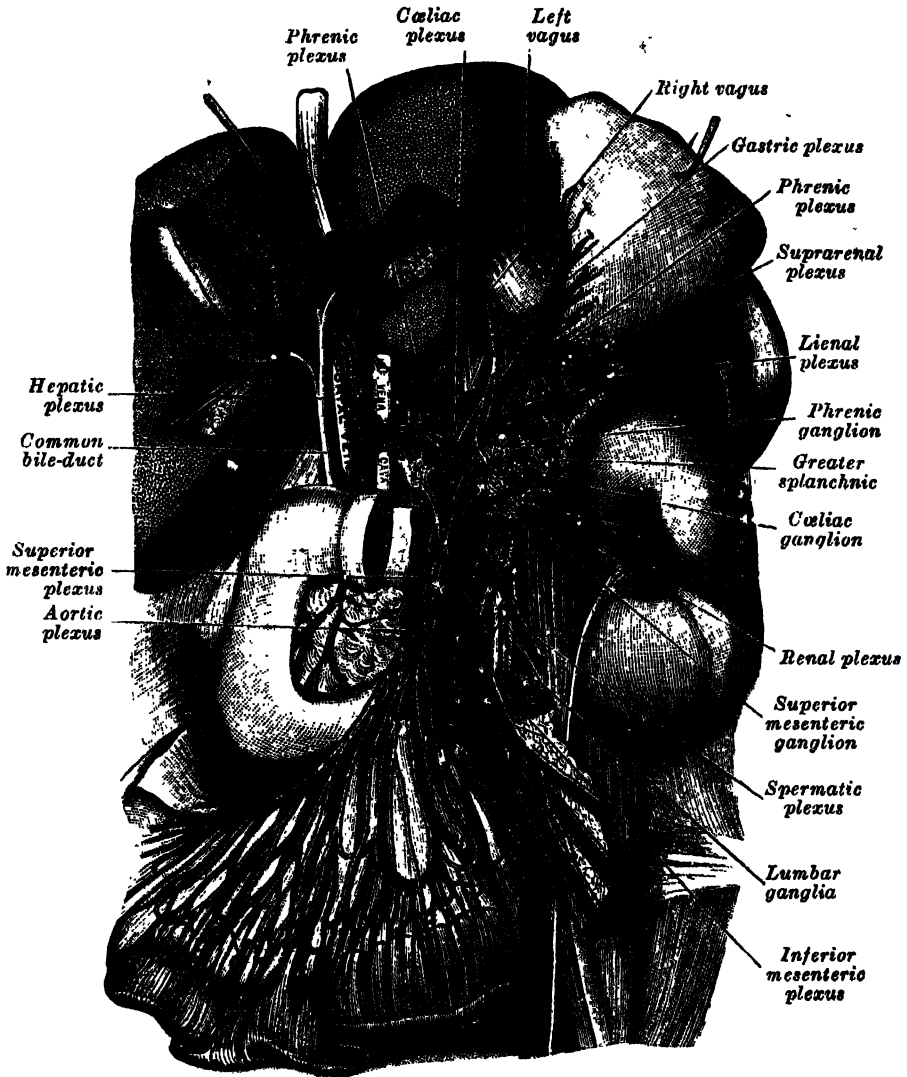
COELIAC PLEXUS (figs. 856, 860)

The coeliac or solar plexus, the largest of the three great sympathetic plexuses, is situated at the level of the upper part of the first lumbar vertebra, and is composed of two large ganglia, the coeliac ganglia, and a dense network of nerve-fibres uniting them together. It surrounds the coeliac artery and the root of the superior mesenteric artery. It lies behind the stomach and the omental bursa, in front of the crura of the Diaphragm and the commencement of the abdominal aorta, and between the suprarenal glands. The plexus and the ganglia receive the greater and lesser splanchnic nerves of both sides

and some filaments from the right vagus, and give off numerous secondary plexuses along the neighbouring arteries.

The *cœliac* or *semilunar ganglia* are two large irregularly-shaped masses having the appearance of lymph-glands, and placed one on either side of the middle line in front of the crura of the Diaphragm close to the suprarenal glands, that on the right side being placed behind the inferior vena cava. The upper part of

FIG. 860.—The *cœliac* ganglia with the sympathetic plexuses of the abdominal viscera radiating from the ganglia. (From Toldt's 'Atlas,' published by Messrs. Rebman, Ltd., London.)



each ganglion is joined by the greater splanchnic nerve, while the lower part, which is more or less detached, and named the *aorticorenal* ganglion, receives the lesser splanchnic nerve and gives off the greater part of the renal plexus.

The secondary plexuses springing from or connected with the *cœliac* plexus are the following :

Phrenic.
Hepatic.
Lienal.
Superior gastric.
Suprarenal.

Renal.
Spermatic.
Superior mesenteric.
Abdominal aortic.
Inferior mesenteric.

The phrenic plexus accompanies the inferior phrenic artery to the Diaphragm, some filaments passing to the suprarenal gland. It arises from the upper part of the coeliac ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. At the point of junction of the right phrenic plexus with the phrenic nerve is a small ganglion (*ganglion phrenicum*). This plexus distributes some branches to the inferior vena cava, and to the suprarenal and hepatic plexuses.

The hepatic plexus, the largest offset from the coeliac plexus, receives filaments from the left vagus and right phrenic nerves. It accompanies the hepatic artery, ramifying upon its branches, and upon those of the portal vein, in the substance of the liver. Branches from this plexus accompany all the branches of the hepatic artery. A considerable plexus accompanies the gastroduodenal artery and is continued as the *inferior gastric plexus* on the right gastro-epiploic artery along the greater curvature of the stomach, where it unites with offshoots from the lienal plexus.

The lienal or splenic plexus is formed by branches from the coeliac plexus, left coeliac ganglion, and right vagus nerve. It accompanies the lienal artery to the spleen, giving off, in its course, subsidiary plexuses along the various branches of the artery.

The superior gastric plexus accompanies the left gastric artery along the lesser curvature of the stomach, and joins with branches from the left vagus.

The suprarenal plexus is formed by branches from the coeliac plexus, from the coeliac ganglion, and from the phrenic and greater splanchnic nerves, a ganglion being formed at the point of junction with the latter nerve. The plexus supplies the suprarenal gland, and is distributed chiefly to its medullary portion; its branches are remarkable for their large size in comparison with that of the organ they supply.

The renal plexus is formed by filaments from the coeliac plexus, the aorticorenal ganglion, and the aortic plexus. It is joined also by the smallest splanchnic nerve. The nerves from these sources, fifteen or twenty in number, have a few ganglia developed upon them. They accompany the branches of the renal artery into the kidney; some filaments are distributed to the spermatic plexus and to the ureter, and, on the right side, to the inferior vena cava.

The spermatic plexus is derived from the renal plexus, receiving branches from the aortic plexus. It accompanies the testicular artery to the testis. In the female, the ovarian plexus arises from the renal plexus, and is distributed to the ovary, and the fundus of the uterus.

Applied Anatomy.—The intimate connexion which exists between the renal and spermatic plexuses serves to explain the very frequent symptom, in renal calculus, of pain which is referred to the body of the testis.

The superior mesenteric plexus is a continuation of the lower part of the coeliac plexus, and receives a branch from the junction of the right vagus nerve with the plexus. It surrounds the superior mesenteric artery, accompanies it into the mesentery, and divides into a number of secondary plexuses which are distributed to all the parts supplied by the artery, viz. pancreatic branches to the pancreas; jejunal and ileal branches to the small intestine; and ileocolic, right colic, and middle colic branches, which supply the corresponding parts of the great intestine. The nerves composing this plexus are white in colour and firm in texture; in the upper part of the plexus close to the origin of the superior mesenteric artery is a ganglion (*ganglion mesentericum superius*).

The abdominal aortic plexus is formed by branches derived, on either side, from the coeliac plexus and ganglia, and receives filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus arise part of the spermatic, the inferior mesenteric, and the hypogastric plexuses; it also distributes filaments to the inferior vena cava.

The inferior mesenteric plexus is derived chiefly from the aortic plexus. It surrounds the inferior mesenteric artery, and just below the origin of this vessel the *inferior mesenteric ganglion* is situated. The plexus divides into a number of secondary plexuses, which are distributed to all the parts supplied.

by the artery; thus the left colic and sigmoid plexuses supply the descending and sigmoid parts of the colon; and the superior hæmorrhoidal plexus, supplies the rectum and joins in the pelvis with branches from the pelvic plexuses.

HYPOGASTRIC PLEXUS (fig. 856)

The **hypogastric plexus** is situated in front of the last lumbar vertebra and the promontory of the sacrum, between the two common iliac arteries. It is formed by the union of numerous filaments, which descend on either side from the aortic plexus, and from the lumbar ganglia. It divides, below, into two lateral portions which are named the *pelvic plexuses*.

PELVIC PLEXUSES (fig. 856)

The **pelvic plexuses** supply the viscera of the pelvic cavity, and are situated at the sides of the rectum in the male, and at the sides of the rectum and vagina in the female. They are formed on either side by a continuation of the hypogastric plexus, by the visceral branches from the second, third, and fourth sacral nerves, and by a few filaments from the first two ganglia of the sacral part of the sympathetic trunk. At the points of junction of these nerves small ganglia are found. From these plexuses numerous branches are distributed to the viscera of the pelvis. They accompany the branches of the hypogastric artery.

The **middle hæmorrhoidal plexus** arises from the upper part of the pelvic plexus; it supplies the rectum, and joins with branches of the superior hæmorrhoidal plexus.

The **vesical plexus** arises from the fore part of the pelvic plexus. The nerves composing it are numerous, and contain a large proportion of spinal nerve-fibres. They accompany the vesical arteries, and are distributed to the sides and fundus of the bladder. Numerous filaments also pass to the vesiculæ seminales and ductus deferentes; those accompanying the ductus deferentes join, on the spermatic cords, with branches from the spermatic plexuses.

The **prostatic plexus** is continued from the lower part of the pelvic plexus. The nerves composing it are of large size. They are distributed to the prostate, vesiculæ seminales, and the corpora cavernosa of the penis and urethra. The nerves supplying the corpora cavernosa consist of two sets, the lesser and greater cavernous nerves, which arise from the fore part of the prostatic plexus, and, after joining with branches from the pudendal nerve, pass forwards beneath the pubic arch.

The *lesser cavernous nerves* perforate the fibrous covering of the penis, near its root, and are distributed to its erectile tissue.

The *greater cavernous nerve* passes forwards along the dorsum of the penis, joins with the dorsal nerve of the penis, and is distributed to the corpora cavernosa.

The **vaginal plexus** arises from the lower part of the pelvic plexus. It is distributed to the walls of the vagina and to the erectile tissue of the vestibule. The nerves composing this plexus contain, like the vesical, a large proportion of spinal nerve-fibres.

The **uterine plexus** accompanies the uterine artery along the side of the uterus, between the layers of the broad ligament, and communicates with the ovarian plexus. Its fibres are chiefly distributed to the neck, and the lower part of the body, of the uterus. At the side of the neck of the uterus is a collection of small ganglia which together form the *uterine cervical ganglion*.

Applied Anatomy.—Little is known as to the connexion between the numerous microscopical alterations (pigmentation, atrophy, hæmorrhage, fibrosis) that have been described in the sympathetic nervous system, and the functional changes that ensue therefrom. Grosser lesions due to stabs, bullet-wounds, or the pressure of new growths, may cause either irritative or paralytic symptoms. In *paralysis* of the cervical sympathetic on one side, the pupil is small and does not dilate when shaded or on the instillation of cocaine, although it contracts still further when brightly illuminated; it also loses the oculo-spinal reflex, failing to dilate when the skin of the neck is pinched. The palpebral fissure narrows from paralysis of the involuntary muscle of the eyelid, and the

eyeball sinks backwards into the orbit—enophthalmos—either from paralysis of Müller's orbital muscle in the eyelids, which surrounds the eyeball like a conical cuff and tends to produce exophthalmos when it contracts, or from wasting of the intraorbital fat. The superficial vessels of the face and scalp are at first dilated, but later they contract. Anidrosis, or absence of sweating, is often noted on the affected side. Irritation of the cervical sympathetic produces signs mainly the converse of those described above. We have no definite knowledge of the signs and symptoms that follow lesions of the thoracic or abdominal sympathetic systems. It is likely, however, that a number of nervous disorders characterised by persistent vascular disturbances, such as dilatation of the vessels with throbbing, flushing, sweating, and localised oedema, or contraction of the vessels with pallor, chilliness, pain, and malnutrition of the affected parts, are due to implication of the sympathetic nervous system. It is possible, too, that the rare condition of *progressive facial hemiatrophy*, coming on between the ages of ten and twenty, and producing marked unilateral shrinkage of all the tissues on the affected side of the face, is primarily an affection of the sympathetic.

THE ORGANS OF THE SENSES AND THE COMMON INTEGUMENT

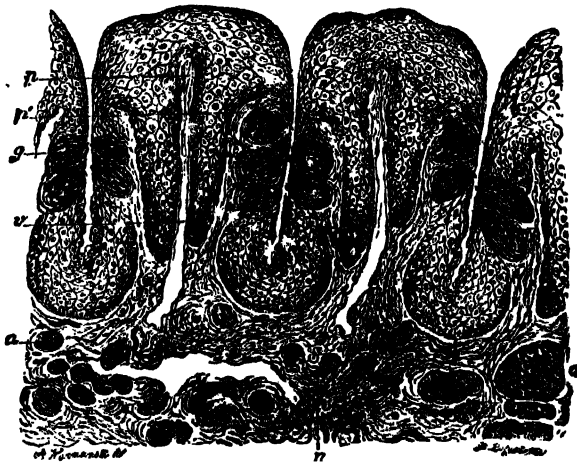
THE organs of the senses may be divided into (a) those of the special senses of taste, smell, sight, and hearing, and (b) those associated with the general sensations of heat, cold, pain, pressure, &c.

PERIPHERAL ORGANS OF THE SPECIAL SENSES

THE ORGAN OF TASTE

The peripheral gustatory organs, or organs of taste, consist of certain modified epithelial cells arranged in flask-shaped groups termed *gustatory calyculi* or

FIG. 861.—A vertical transverse section of the papilla foliata of the rabbit. (Ranvier.)



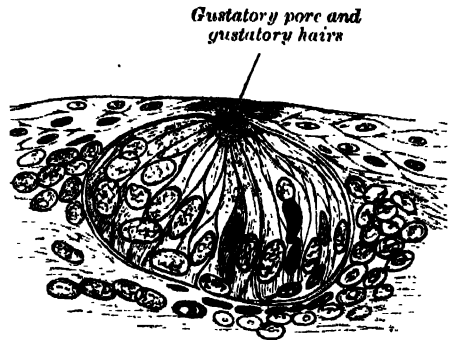
a. Serous gland. g. Gustatory calyculus. n. Nerve-bundles. p. Central lamina of the corium. p'. Lateral lamina in which the nerve-fibres run. v. Sinus-like vein which traverses the whole length of the folium.

taste-buds, which are found on the tongue and adjacent parts. They occupy nests in the stratified epithelium (fig. 861), and are very numerous on the sides of the papillæ vallatæ and less so on the walls surrounding the papillæ. They are also found on the fungiform papillæ over the posterior part and sides of the tongue, and in the general epithelial covering of the same areas. They are very plentiful over the fimbriæ linguæ, and are also present on the under surface of the soft palate, and on the posterior surface of the epiglottis.

Structure.—Each taste-bud is flask-shaped (fig. 862), its broad base resting on the corium, and its neck opening by an orifice, the *gustatory pore*, between the cells of the epithelium. The bud consists of supporting cells and gustatory cells. The *supporting cells* are mostly arranged like the staves

of a cask, and form a complete envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The *gustatory cells* occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near the middle of the cell. The peripheral process of the cell ends at the gustatory pore in a fine hair-like filament, the *gustatory hair*. The central process passes towards the deep extremity of the bud, and there ends in a single or branched extremity. The nerve-fibres, after losing their medullary sheaths, enter the taste-bud, and end in fine fibrils between the gustatory cells; other nerve-fibrils end between the epithelial cells which surround the taste-bud, but these are believed to be nerves of ordinary sensation and not gustatory.

FIG. 862.—A taste-bud, highly magnified.



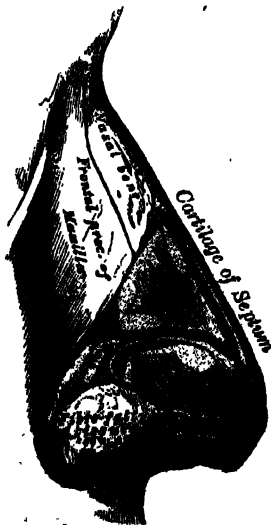
Nerves of taste.—The chorda tympani nerve, derived from the sensory root of the facial nerve, and distributed with the lingual nerve, is the nerve of taste for the anterior two-thirds of the tongue; the glossopharyngeal is the nerve of taste for the posterior one-third of the tongue.

THE ORGAN OF SMELL

The peripheral olfactory organ or organ of smell consists of two parts: an outer, the *external nose*, which projects from the centre of the face; and an internal, the *nasal cavity*, which is divided by a septum into *right* and *left nasal chambers*.

The *external nose* is pyramidal in form, and its upper angle or *root* is connected directly with the forehead; its free angle is termed the *apex*. Its *base* is perforated by two elliptical orifices, the *nares*, separated from each other by an antero-posterior septum, the *columna*. The lateral surfaces of the nose form, by their union in the middle line, the *dorsum nasi*, the direction of which varies considerably in different individuals; the upper part of the dorsum is supported by the nasal bones, and is named the *bridge*. The lateral surfaces end below in rounded eminences, the *ala nasi*.

FIG. 863.—The cartilages of the nose. Side view.

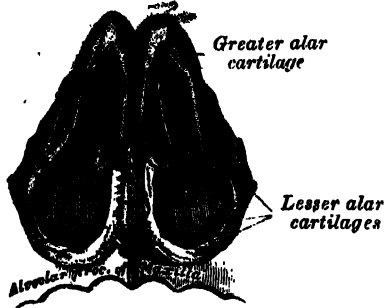


The framework of the external nose is composed of bones and cartilages. The *bony framework* occupies the upper part of the organ; it consists of the nasal bones, the frontal processes of the maxillæ, and the nasal part of the frontal bone. The *cartilaginous framework* consists of five large pieces, viz. the cartilage of the septum, the two lateral, and the two greater alar, cartilages, and several smaller pieces, the lesser alar cartilages (figs. 863, 864, 865). The various cartilages are connected to each other and to the bones by a tough fibrous membrane.

The *cartilage of the septum* is somewhat quadrilateral in form, thicker at its margins than at its centre, and completes the separation between the nasal cavities in front. Its anterior margin, thickest above, is connected with the nasal bones, and is continuous with the anterior margins of the lateral cartilages; below, it is connected to the medial crura of the greater alar cartilages by fibrous tissue. Its posterior margin is connected with the lamina perpendicularis of the

ethmoidal bone; its lower margin with the vomer and the incisor crest of the maxillæ. It may extend backwards (especially in children) as a narrow process, the *sphenoidal process*, for some distance between the vomer and the lamina perpendicularis of the ethmoidal bone. In front, the septal cartilage does not

FIG. 864.—The cartilages of the nose.
From below.



form the lower part of the nasal septum. This is formed by the medial crura of the greater alar cartilages and by the skin; it is freely movable, and hence is termed the *septum mobile nasi*.

The *lateral cartilage* is situated below the inferior margin of the nasal bone, and is flattened, and triangular in shape. Its anterior margin is thicker than the posterior, and is continuous above with the cartilage of the septum, but separated from it below by a narrow fissure; its superior margin is attached to the nasal bone and the frontal process of the maxilla; its inferior margin is connected by fibrous tissue with the greater alar cartilage.

The *greater alar cartilage* is a thin, flexible plate, situated immediately below the lateral cartilage, and bent upon itself in such a manner as to form the medial, anterior, and lateral walls of the naris of its own side. The portion which forms the medial wall (*crus mediale*) is narrow, and is loosely connected with the corresponding portion of the opposite cartilage, the two forming, together with the thickened skin and subjacent tissue, the *septum mobile nasi*. The part which forms the lateral wall (*crus laterale*) is curved to correspond with the ala of the nose; it is oval and flattened, narrow behind, where it is connected with the frontal process of the maxilla by a tough fibrous membrane, in which are found three or four small cartilaginous plates, the *lesser alar cartilages*. Above, it is connected by fibrous tissue to the lateral cartilage and front part of the cartilage of the septum; below, it falls short of the lateral margin of the naris, the ala being completed by fatty and fibrous tissue covered by skin. In front, the greater alar cartilages are separated by a notch which corresponds with the apex of the nose.

FIG. 865.—The bones and cartilages of the septum of the nose. Right side.



The *muscles* acting on the external nose have been described on p. 429.

The *skin* of the dorsum and sides of the nose is thin, and loosely connected with the subjacent parts; but over the tip and ala it is thicker and more firmly adherent, and is furnished with a large number of sebaceous follicles, the orifices of which are usually very distinct.

The *arteries* of the external nose are the alar and septal branches of the external maxillary artery, which supply the alæ and septum; the dorsum and sides being supplied from the dorsal nasal branch of the ophthalmic artery and the infraorbital branch of the internal maxillary artery. The *veins* end in the anterior facial and ophthalmic veins.

The *nerves* for the muscles of the nose are derived from the facial nerve, while the skin receives branches from the infratrochlear and anterior ethmoidal branches of the ophthalmic nerve, and from the infraorbital branch of the maxillary nerve.

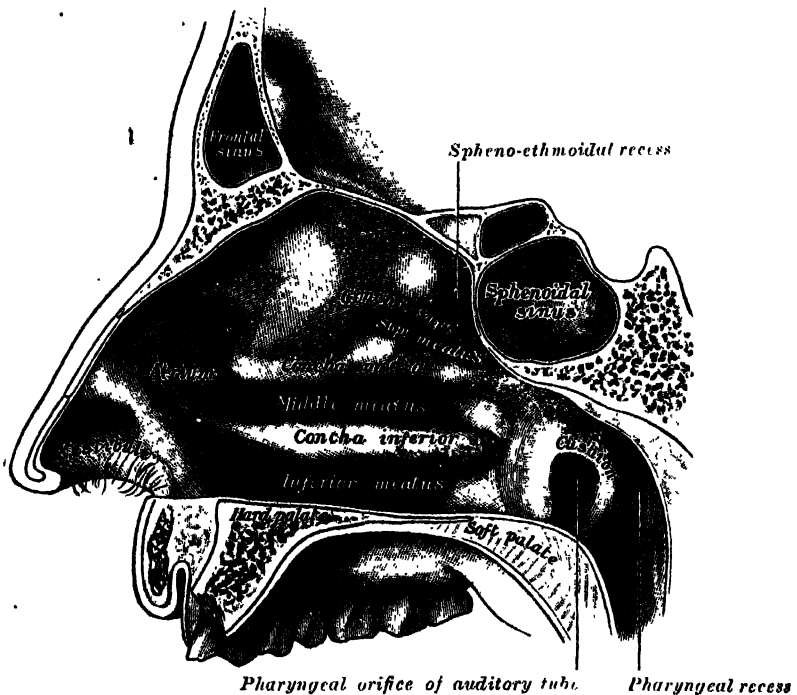
Nasal cavities.—The nasal cavities or chambers are situated one on either side of the median plane. They open in front through the nares, and communicate behind with the nasal part of the pharynx through the choanae. The *nares* are somewhat pear-shaped apertures, each measuring from 1.5 cm.

to 2 cm. anteroposteriorly, and from 0.5 cm. to 1 cm. transversely at its widest part. The *choanae* are two oval openings each measuring 2.5 cm. in the vertical, and 1.25 cm. in the transverse direction in a well-developed adult skull.

For the description of the bony boundaries of the nasal cavities, see p. 256.

Inside the aperture of the nostril is a slight dilatation, the *vestibule*, bounded laterally by the ala and the lateral crus of the greater alar cartilage, and medially by the medial crus of the same cartilage; it extends as a small recess towards the apex of the nose. The vestibule is lined by skin, and in its lower part are coarse hairs and sebaceous glands; the hairs (*vibrissae*) curve downwards and forwards and arrest the passage of foreign substances carried with the current of inspired air. The vestibule is limited above and behind by a curved elevation, the *limen nasi*, along which the cutaneous lining of the vestibule is continuous with the mucous membrane of the nasal cavity.

FIG. 866.—The lateral wall of the right nasal cavity.

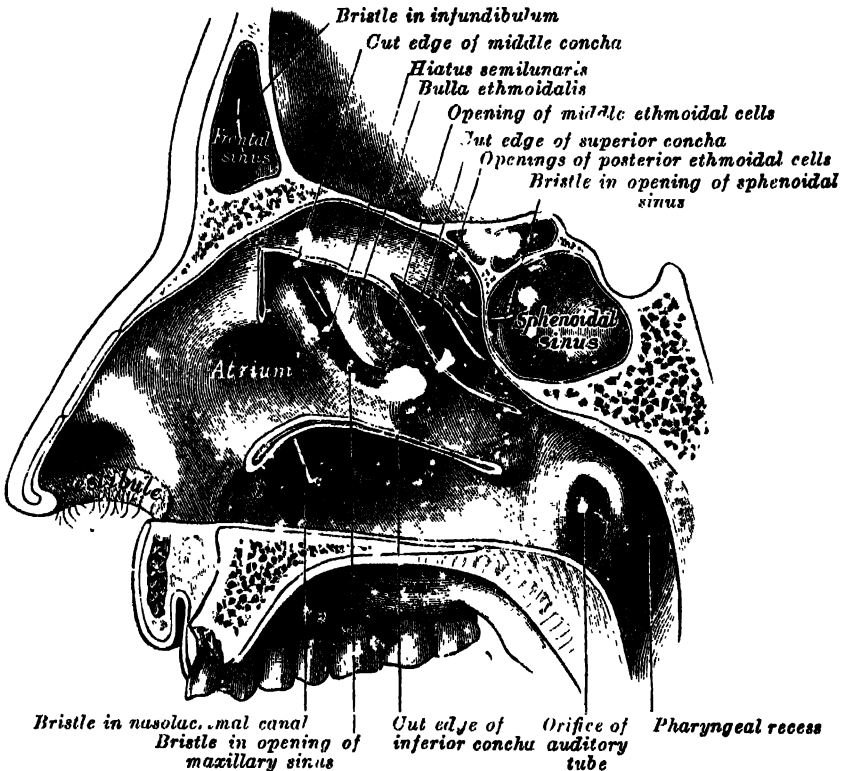


Each nasal cavity, above and behind the vestibule, is divided into two parts: an *olfactory* region, limited to the superior nasal concha and the opposed part of the septum, and a *respiratory* region, which comprises the rest of the cavity.

Lateral wall (figs. 866, 867).—On the lateral wall are the superior, middle, and inferior nasal conchæ, and below and lateral to each concha is the corresponding nasal passage or meatus. Above the superior concha is a triangular fossa, the *spheno-ethmoidal recess*, into which the sphenoidal sinus opens. The *superior meatus* is a short oblique passage extending about half-way along the upper border of the middle concha; the posterior ethmoidal cells open, usually by two apertures, into the front part of this meatus. The *middle meatus*, deeper in front than behind, is below and lateral to the middle concha, and is continued anteriorly into a shallow depression, situated above the vestibule and named the *atrium* of the middle meatus. Above the atrium a flattened ridge, termed the *agger nasi*, and better developed in the new-born child than in the adult, runs forwards and downwards; the furrow above

it is named the *sulcus olfactorius*. On raising or removing the middle concha the lateral wall of this meatus is fully displayed. On it is a round elevation, the *bullæ ethmoidalis*, and below and in front of this is a curved cleft, the *hiatus semilunaris*. The *bullæ ethmoidalis* is caused by the bulging of the middle ethmoidal cells which open on or immediately above it, and the size of the bulla varies with that of its contained cells. The *hiatus semilunaris* is bounded inferiorly by the sharp concave margin of the uncinæ process of the ethmoidal bone, and leads into a curved channel, the *infundibulum*, bounded above by the bulla ethmoidalis and below by the lateral surface of the uncinæ process of the ethmoidal bone. The anterior ethmoidal cells open into the front part of the infundibulum; the latter in rather more than 50 per cent.

FIG. 867.—The lateral wall of the right nasal cavity; the three nasal conchæ have been removed.



of subjects is continuous with the frontonasal duct or passage leading from the frontal air-sinus; but in those cases where the anterior end of the uncinæ process fuses with the front part of the bulla, this continuity is interrupted and the frontonasal duct then opens directly into the anterior end of the middle meatus. Below the bulla ethmoidalis, and partly hidden by the inferior end of the uncinæ process, is the *ostium maxillare*, or opening from the maxillary sinus; in a frontal section of the nose this opening is seen to be placed near the roof of the sinus. An accessory opening from the sinus is frequently present below and behind the infundibulum. The *inferior meatus* is below and lateral to the inferior nasal concha; the nasolacrimal duct opens into this meatus under cover of the anterior part of the inferior concha.

Medial wall (fig. 865).—The medial wall or septum is frequently more or less deflected from the median plane, thus lessening the size of one nasal cavity and increasing that of the other; ridges or spurs of bone growing into one or other cavity from the septum are also sometimes present. Immediately over the incisive canal at the lower edge of the cartilage of the septum a depression, the *nasopalatine recess*, is sometimes seen; it points downwards and forwards,

and occupies the position of a canal which connected the nasal with the buccal cavity in early foetal life. In the septum close to this recess a minute orifice may be discerned; it leads backwards into a blind pouch, the rudimentary *vomeranasal organ of Jacobson*, which is supported by a strip of cartilage, the *vomeranasal cartilage*. This organ is well developed in many of the lower animals, where it apparently plays a part in the sense of smell, since it is supplied by twigs of the olfactory nerve and is lined by epithelium similar to that in the olfactory region of the nose.

The *roof* of the nasal cavity is narrow from side to side, except at its posterior part, and may be divided, from behind forwards, into sphenoidal, ethmoidal, and frontonasal parts, corresponding to the bones which form it.

The *floor* is concave from side to side, flat and almost horizontal antero-posteriorly; its anterior three-fourths are formed by the palatine process of the maxilla, its posterior fourth by the horizontal part of the palatine bone.

The *nasal mucous membrane* lines the nasal cavities with the exception of the vestibules, and is intimately adherent to the periosteum or perichondrium.

FIG. 868.—A section of the olfactory mucous membrane. (Cadiat.)



a. Epithelium. b. Glands of Bowman. c. Nerve-bundles.

It is continuous with the mucous membrane of the nasal part of the pharynx, through the choanæ; with the conjunctiva, through the nasolacrimal and lacrimal ducts; and with the mucous membranes of the frontal, ethmoidal, sphenoidal, and maxillary sinuses, through the openings of these sinuses into the sphenoidal recess and the superior and middle meatuses.

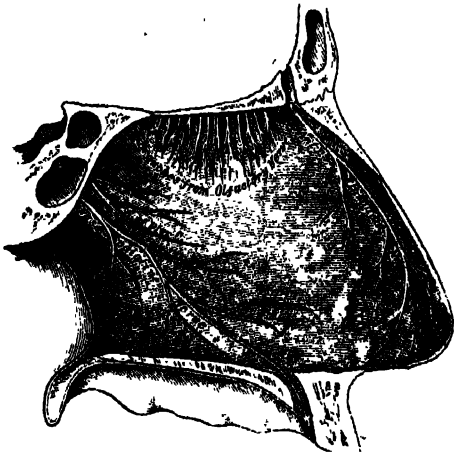
The mucous membrane is thickest and most vascular over the nasal conchæ, especially at their extremities. It is also thick over the septum nasi; but it is very thin in the meatuses, on the floor of the nasal cavities, and in the various air-sinuses. Owing to the thickness of the membrane, the nasal cavities are much narrower, and the middle and inferior nasal conchæ appear larger and more prominent than in the skeleton; the various apertures communicating with the meatuses are also considerably narrowed.

Structure of the mucous membrane (fig. 868).—The epithelium of the mucous membrane differs in its characteristics according to the functions of the part of the nose in which it is found. In the *respiratory region* it is columnar and ciliated. Interspersed among the columnar cells are goblet or mucous cells, while between their bases are found smaller pyramidal cells. Beneath the epithelium and its basement membrane is a fibrous layer infiltrated with lymph-corpuscles, forming in many parts a diffuse adenoid tissue, and under this a nearly continuous layer of smaller and larger glands, some mucous and some serous, the ducts of which open upon the surface. In the *olfactory region* the mucous membrane is yellowish in colour and the epithelial cells are columnar and non-ciliated; they are of two kinds, supporting cells and olfactory cells.

The *supporting cells* contain oval nuclei, which are situated in the deeper parts of the cells and constitute the zone of oval nuclei; the superficial part of each cell is columnar, and contains granules of yellow pigment, while its deep part is prolonged as a delicate process which ramifies, and communicates with similar processes from neighbouring cells so as to form a network in the mucous membrane. Lying between the deep processes of the supporting cells are a number of bipolar nerve-cells, the *olfactory cells*, each consisting of a small amount of granular protoplasm with a large spherical nucleus, and possessing two processes—a superficial process which runs between the columnar epithelial cells, and ends at the surface of the mucous membrane in one or more fine, hair-like processes, the *olfactory hairs*; the deep process runs inwards, is frequently beaded, and is continued as an olfactory nerve-fibre (p. 847). Beneath the epithelium, and extending through the thickness of the mucous membrane, is a layer of tubular, often branched, glands, the *glands of Bowman*, similar in structure to serous glands.

Vessels and Nerves.—The *arteries* of the nasal cavities are the anterior and posterior ethmoidal branches of the ophthalmic artery, which supply the ethmoidal cells, frontal sinuses, and roof of the nose; the sphenopalatine branch of the internal maxillary artery, which supplies the mucous membrane covering the conchæ, the meatuses, and septum;

FIG. 869.—The nerves of the septum of the nose. Right side.



the septal ramus of the superior labial branch of the external maxillary artery; the infraorbital and alveolar branches of the internal maxillary artery, which supply the lining membrane of the maxillary sinus; and the pharyngeal branch of the same artery, distributed to the sphenoidal sinus. The ramifications of these vessels form a close plexiform network, beneath and in the substance of the mucous membrane.

The *veins* form a close cavernous plexus beneath the mucous membrane. This plexus is especially marked over the lower part of the septum and over the middle and inferior conchæ. Some of the veins open into the sphenopalatine vein; others join the anterior facial vein; some accompany the ethmoidal arteries, and end in the ophthalmic veins; a few communicate with the veins on the orbital surface of the

frontal lobe of the brain, through the foramina in the lamina cribrosa of the ethmoidal bone. When the foramen cecum is patent it transmits a vein from the nasal cavity to the superior sagittal sinus.

The *lymphatics* are described on p. 717.

The *nerves* of ordinary sensation are: the anterior ethmoidal branch of the nasociliary nerve, filaments from the anterior alveolar branch of the maxillary nerve, the nerve of the pterygoid canal, the nasopalatine, the anterior palatine and nasal branches of the sphenopalatine ganglion.

The anterior ethmoidal branch of the nasociliary nerve distributes filaments to the anterior parts of the septum and lateral wall. Filaments from the anterior alveolar nerve supply the inferior meatus and inferior concha. The nerve of the pterygoid canal supplies the upper and posterior parts of the septum, and superior concha; and the upper nasal branches from the sphenopalatine ganglion have a similar distribution. The nasopalatine nerve supplies the middle of the septum. The anterior palatine nerve supplies the lower nasal branches to the middle and inferior conchæ.

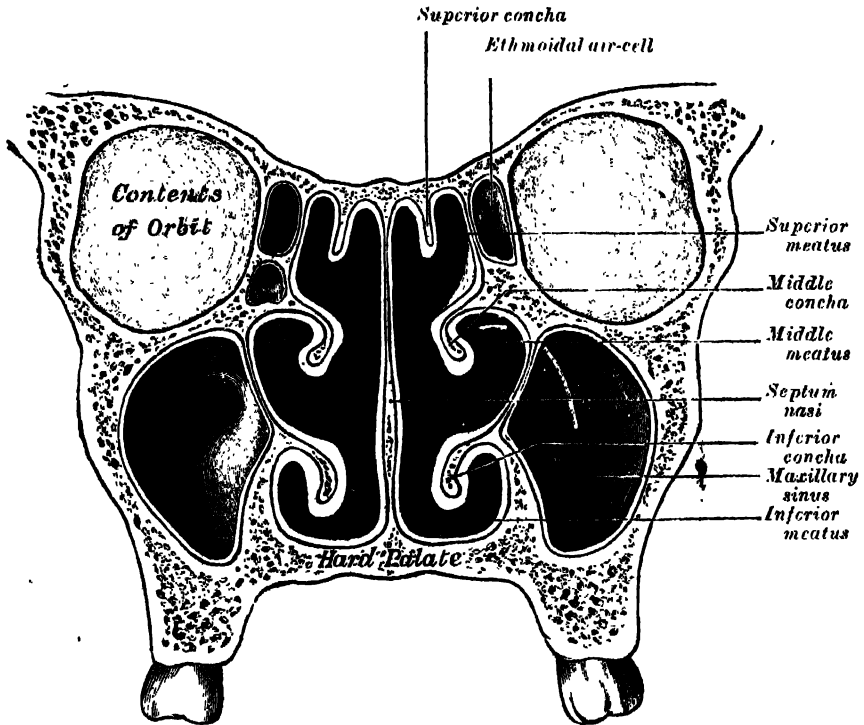
The *olfactory nerve* is distributed to the olfactory region. Its fibres arise from the bipolar olfactory cells and are destitute of medullary sheaths. They unite in fasciculi which cross one another in various directions, and thus give rise to the appearance of a plexus in the mucous membrane, and then ascend in grooves or canals in the ethmoidal bone; they pass into the skull through the foramina in the lamina cribrosa of the ethmoid and enter the under surface of the olfactory bulb, in which they ramify and form synapses with the dendrites of the mitral cells (fig. 806).

ACCESSORY SINUSES OF THE NOSE (figs. 866, 867, 870)

The **accessory sinuses** or **air-cells** of the nose are the frontal, ethmoidal, sphenoidal, and maxillary; they vary in size and form in different individuals, and are lined by mucous membrane continuous with that of the nasal cavities.

The **frontal sinuses**, two in number, are situated behind the superciliary arches; they are rarely symmetrical, and the septum between them frequently deviates to one or other side of the middle line. Their average measurements are as follows: height, 3.16 cm.; breadth, 2.58 cm.; depth from before backwards, 1.8 cm. Each opens into the anterior part of the corresponding middle meatus of the nose through the frontonasal duct, which traverses the anterior part of the labyrinth of the ethmoid. Small at birth, they are generally fairly well developed between the seventh and eighth years, but only reach their full size after puberty.

Fig. 870.—A coronal section of the nasal cavities.



The **ethmoidal air-cells** consist of numerous thin-walled cavities situated in the ethmoidal labyrinth, and completed by the frontal, maxillary, lacrimal, sphenoidal and palatine bones. They lie between the upper parts of the nasal cavities and the orbits, and are separated from the latter by thin bony laminae. On either side they are arranged in three groups, anterior, middle, and posterior. The anterior and middle groups open into the middle meatus of the nose, the former by way of the infundibulum, the latter on or above the bulla ethmoidalis. The posterior cells open into the superior meatus under cover of the superior nasal concha; sometimes one or more opens into the sphenoidal sinus. The ethmoidal cells begin to develop during foetal life.

The **sphenoidal sinuses**, two in number, are contained within the body of the sphenoidal bone; they vary in size and shape, and, owing to the lateral displacement of the intervening septum, are rarely symmetrical. The following are their average measurements: vertical height, 2 cm.; transverse breadth, 1.8 cm.; antero-posterior depth, 2.1 cm. When exceptionally large they may extend into the roots of the pterygoid processes or great wings, and may invade the basilar part of the occipital bone. Each sinus communicates with the spheno-ethmoidal recess by

an aperture in the upper part of its anterior wall. They are present as minute cavities at birth, but their main development takes place after puberty.

The **maxillary sinus** or **antrum of Highmore**, the largest of the accessory sinuses of the nose, is a pyramidal cavity in the body of the maxilla. Its base is formed by the lateral wall of the nasal cavity, and its apex extends into the zygomatic process. Its roof or orbital wall is frequently ridged by the infraorbital canal, while its floor is formed by the alveolar process and is usually about 1.25 cm. below the level of the floor of the nose; projecting into the floor are several conical elevations corresponding with the roots of the first and second molar teeth, and in some cases it is perforated by one or more of these roots. The size of the sinus varies in different skulls, and even on the two sides of the same skull; when large, its apex may invade the zygomatic bone. The following measurements are those of an average-sized sinus: vertical height opposite the first molar tooth, 3.5 cm.; transverse breadth, 2.5 cm.; anteroposterior depth, 3.2 cm. In the anterosuperior part of its base is an opening through which it communicates with the lower part of the hiatus semilunaris; a second orifice is frequently seen in, or immediately behind, the hiatus. The maxillary sinus appears as a shallow groove on the medial surface of the bone about the fourth month of fetal life, but does not reach its full size until after the second dentition.*

Applied Anatomy.—Instances of congenital deformity of the nose are occasionally met with, such as complete absence of the external nose, an aperture only being present, or perfect development on one side, and suppression or malformation on the other. Deformities which have been acquired are much more common, such as flattening of the nose, the result of syphilitic necrosis; or imperfect development of the nasal bones in cases of congenital syphilis; or a lateral deviation of the nose after fracture.

The septum of the nose may be displaced or may deviate from the middle line as a result of an injury or of some congenital defect. Sometimes the deviation may be so great that the septum may come into contact with the lateral wall of the nasal cavity, producing complete unilateral obstruction. The septum is covered by a mucous membrane intimately connected with the periosteum; in cases of deflection of the septum, *submucous resection* is frequently necessary, the septal cartilage and the vomer being shelled out from the mucoperiosteum clothing them. Perforation of the septum is not uncommon, and most often results from syphilitic ulceration.

Enlargement of the mucous membrane covering the inferior or middle nasal conchæ is a very frequent accompaniment of chronic nasal catarrh. In old-standing cases the bones themselves may become enlarged, constituting the 'hypertrophied turbinals' which so often cause nasal obstruction. In the case of the inferior concha either the anterior or posterior end is usually more especially affected, giving rise to a reddened mass of tissue often confused with a nasal polypus; the appearances, however, are totally different, as the true nasal polypi appear as glistening greyish-white bodies between the conchæ.

Nasal polypi are of frequent occurrence; in the common gelatinous form they spring from the lateral wall of the nasal cavity and project down between the conchæ, giving rise to obstructed nasal respiration. They are always accompanied by purulent discharge, and are due in all instances to small areas of carious bone in the region of the *bullæ ethmoidalis*, or about the ethmoidal or sphenoidal air-cells. In bad cases a free curetting of the ethmoidal air-cells may be called for after removal of the middle concha. Fibrous polypi are also more rarely met with, and these are of the nature of new growths; they most frequently spring from the base of the skull behind the choanæ and form pedunculated tumours occupying the nasopharynx. Malignant polypi also occur, most commonly originating in the maxillary sinus and projecting through its medial wall into the nasal cavity; for such cases removal of the maxilla offers the only hope of cure.

Suppuration in the accessory nasal sinuses is of frequent occurrence, and in connexion with this the situations at which the various sinuses normally communicate with the nasal cavities, are important: thus one finds they fall into two main groups: the anterior, opening into the middle meatus, and draining the maxillary sinus, the frontal sinus, and the anterior ethmoidal air-cells; and the posterior group, opening into the superior meatus and sphenoid-ethmoidal recess, and draining the posterior ethmoidal and sphenoidal air-cells. Suppuration in the anterior group is the more common, and the pus can be seen running down over the anterior end of the inferior concha, whereas in the case of the posterior group, the pus does not come forwards, but runs back into the nasopharynx over the posterior end of the middle concha. Again, it is of importance to notice that the middle meatus is of such a form that pus running down from the frontal sinus is directed by the groove beneath the *bullæ ethmoidalis* into the ostium of the maxillary sinus, so that the latter sinus may, in some cases, act as a secondary reservoir for pus discharged from the frontal sinus. All the accessory sinuses can be and are infected from the nasal cavity, but it should be noted that in the case of the maxillary sinus, the infection is frequently

* The various measurements of the accessory sinuses of the nose are those given by A. Logan Turner, *Accessory Sinuses of the Nose*, 1901.

conveyed in another way, and that is from the teeth. This sinus is the one most frequently the seat of chronic suppuration and it often requires drainage; this can be carried out by drilling a hole through the alveolus after removal of a tooth, preferably the first molar, or by gouging away the anterior surface of the maxilla, after having reflected the gum, or by removing bone from the lateral wall of the inferior meatus of the nose. Simple drainage, however, is not usually sufficient, and more extensive operations have often to be performed. Distension of the walls of the maxillary antrum occurs as the result of new growth or cyst formation within its cavity. Thus the facial surface may be prominently bulged outwards, upward extension may displace the eyeball, or the nasal cavity on that side may be occluded, giving rise to unilateral obstruction. In some cases the disease will perforate the palatine process of the maxilla and a soft spot will be found under the mucoperiosteum. If the disease be malignant in nature, nothing short of excision of the maxilla is of any avail (p. 265).

THE ORGAN OF SIGHT

The bulb of the eye (eyeball), or organ of sight, is contained in the cavity of the orbit, where it is protected from injury, and can be moved by the ocular muscles. Associated with it are certain accessory structures, viz. the muscles, fasciæ, eyebrows, eyelids, conjunctiva, and lacrimal apparatus.

The bulb of the eye, enveloped by a thin membranous sac, the *fascia bulbi* (p. 972), is imbedded in the fat of the orbit. It is composed of segments of two hollow spheres of different sizes. The anterior segment is one of a small sphere; it is transparent, and forms about one-sixth of the bulb. It is more prominent than the posterior segment, which is one of a larger sphere, and is opaque, and forms about five-sixths of the bulb. The term *anterior pole* is applied to the central point of the anterior curvature of the bulb, and that of *posterior pole* to the central point of its posterior curvature; a line joining the two poles forms the *optic axis*. The axes of the two bulbs are nearly parallel, and therefore do not correspond with the axes of the orbits, which are directed forwards and lateralwards. The optic nerves follow the direction of the axes of the orbits, and are therefore not parallel; each enters its eyeball 3 mm. to the nasal side of and a little below the level of the posterior pole. The bulb measures rather more in its transverse and anteroposterior diameters than in its vertical diameter, the former amounting to about 24 mm., the latter to about 23.5 mm.; its anteroposterior diameter at birth is about 17.5 mm. and at puberty from 20 to 21 mm. In the female all three diameters are rather less than in the male.

The bulb of the eye is composed of three tunics, enclosing three refracting media.

TUNICS OF THE EYE (fig. 871)

From without inwards the three tunics are: (1) A fibrous tunic, consisting of the *sclera* behind and the *cornea* in front; (2) a vascular pigmented tunic, comprising, from behind forwards, the *chorioid*, *ciliary body*, and *iris*; and (3) a nervous tunic, the *retina*.

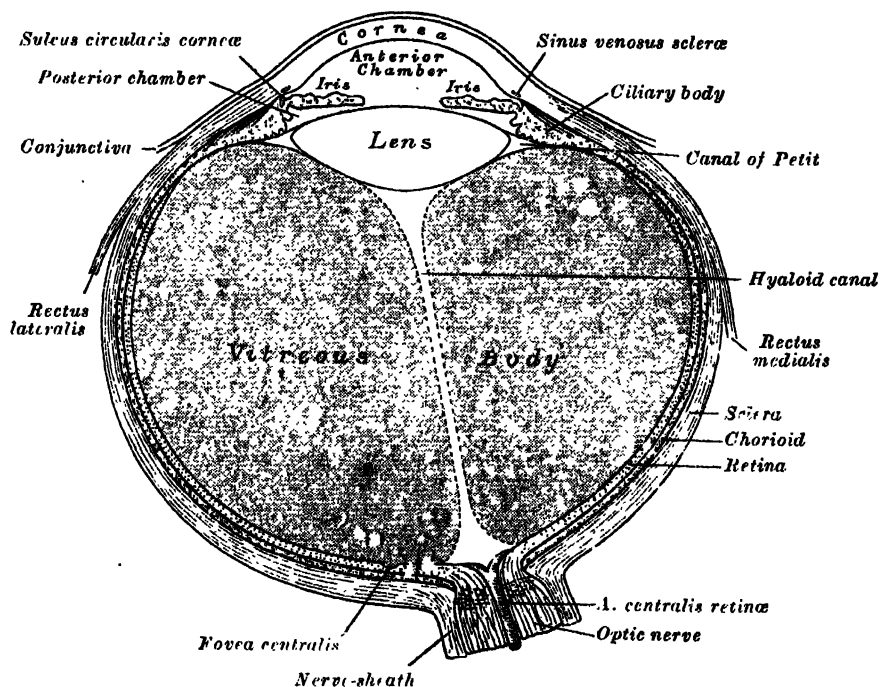
I. FIBROUS TUNIC

The sclera and cornea (fig. 871) form the fibrous tunic of the bulb of the eye; the sclera is opaque, and constitutes the posterior five-sixths of the tunic; the cornea is transparent, and forms the anterior one-sixth.

The sclera has received its name from its extreme density and hardness; it is a firm unyielding membrane, serving to maintain the form of the bulb. It is thickest (about 1 mm.) behind, near the entrance of the optic nerve, and thinnest (0.4 mm.) at a distance of about 6 mm. behind the sclerocorneal junction. Its *external surface* is white, and is in contact with the inner surface of the fascia of the bulb; it is smooth, except where the Recti and Obliqui are inserted into it; its anterior part is covered by the conjunctival membrane. Its *inner surface* is brown and is marked by grooves, in which the ciliary nerves and vessels are lodged; it is separated from the outer surface of the chorioid by an extensive *perichorioid* lymph-space, which is traversed by an exceedingly

fine cellular tissue, the *lamina suprachorioidea*. Behind, it is pierced by the optic nerve, and is continuous through the fibrous sheath of this nerve with the dura mater. The optic nerve pierces the sclera through a cribriform lamina, the *lamina cribrosa scleræ*; the minute orifices in this lamina serve for the transmission of the nervous filaments, and the fibrous septa dividing them from one another are continuous with the supporting trabeculæ of the nerve. One opening, larger than the rest, occupies the centre of the lamina; it transmits the central artery and vein of the retina. Around the lamina cribrosa scleræ are numerous small apertures for the transmission of the ciliary vessels and nerves, and about midway between these and the sclerocorneal junction are four or five large apertures for the transmission of veins (*venæ vorticosæ*). In front, the sclera is directly continuous with the cornea, the line of union being termed the *sclerocorneal junction*. In the substance of the sclera close

FIG. 871.—A horizontal section of the bulb of the eye.



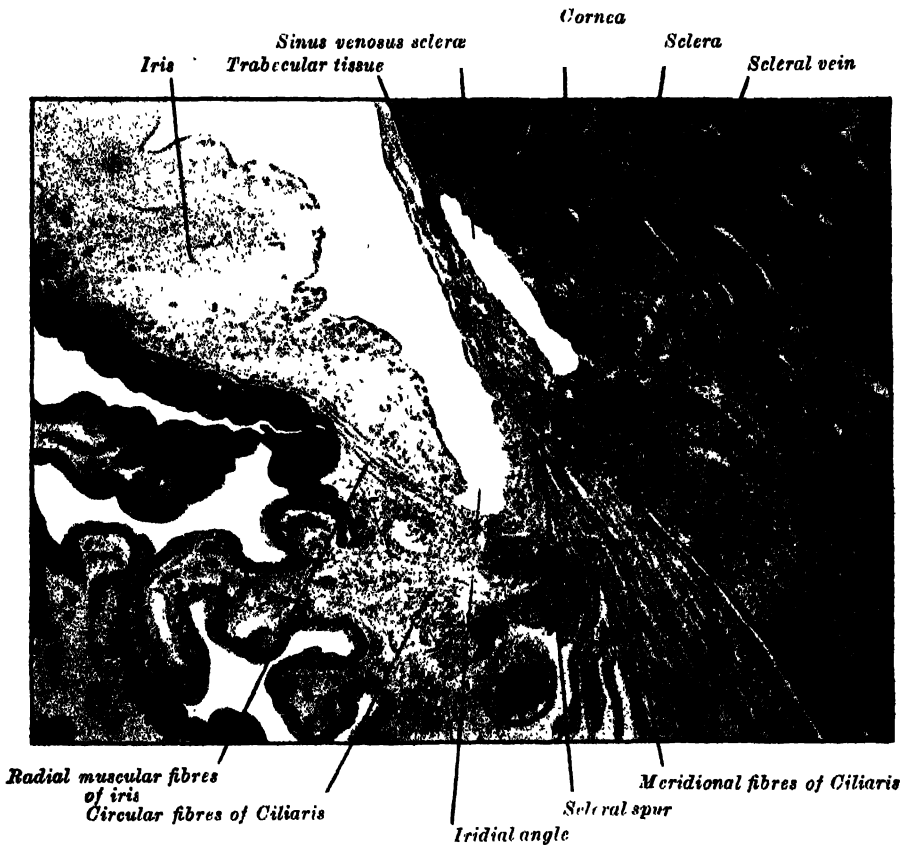
to this junction is a circular canal, the *sinus venosus scleræ* (canal of Schlemm). In a meridional section of the sclerocorneal junction this sinus presents the appearance of a cleft, the outer wall of which consists of the firm tissue of the sclera, while its inner wall is formed by a triangular mass of trabecular tissue (fig. 872); the apex of the mass is directed forwards and is continuous with the posterior elastic lamina of the cornea. The sinus is lined by endothelium and communicates internally with the anterior chamber of the eye and externally with the anterior ciliary veins.

Structure.—The sclera is formed of white fibrous tissue intermixed with fine elastic fibres; flattened connective tissue corpuscles, some of which are pigmented, are contained in cell-spaces between the fibres. The fibres are aggregated into bundles, which are arranged chiefly in a longitudinal direction. Its *vessels* are not numerous; its capillaries are small, and unite at long and wide intervals. Its *nerves* are derived from the ciliary nerves, but their exact mode of ending is not known.

The cornea is the projecting transparent part of the external tunic, and forms the anterior one-sixth of the surface of the bulb. It is almost circular in

outline, occasionally a little broader in the transverse than in the vertical direction. It is convex anteriorly, and projects like a dome in front of the sclera. Its degree of curvature varies in different individuals, and in the same individual at different periods of life, being more pronounced in youth than in advanced life. The cornea is dense and of uniform thickness throughout; its posterior surface is perfectly circular in outline, and exceeds the anterior surface slightly in diameter. Immediately in front of the sclerocorneal junction the cornea bulges inwards as a thickened rim, and behind this there is a distinct furrow between the attachment of the iris and the sclerocorneal junction. This furrow has been named by Arthur Thomson * the *sulcus circularis corneæ*;

FIG. 872.—An enlarged general view of the iridial angle. (Arthur Thomson.)



it is bounded externally by the trabecular tissue already described as forming the inner wall of the sinus venosus scleræ. Between this tissue and the anterior surface of the attached margin of the iris is an angular recess, named the *iridial angle* or *filtration angle* of the eye (fig. 872). Immediately outside the filtration angle is a projecting rim of scleral tissue which appears in a meridional section as a small triangular area, termed the *scleral spur*. Its base is continuous with the inner surface of the sclera immediately to the outer side of the filtration angle and its apex is directed forwards and inwards. The bundles of trabecular tissue just referred to are attached to the anterior sloping margin of this spur; the meridional fibres of the Ciliaris muscle arise from its posterior margin.

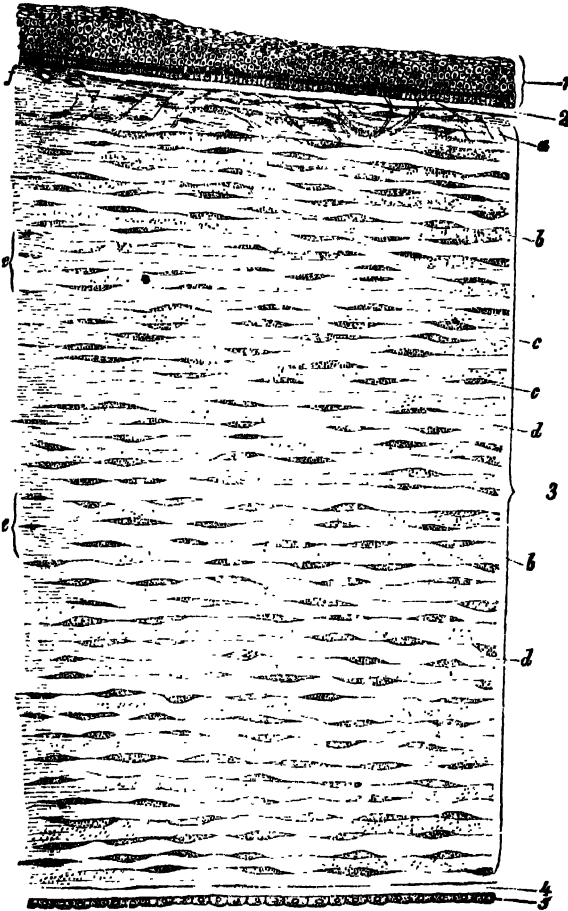
Structure (fig. 873).—The cornea consists from before backwards of four layers, viz.: (1) the corneal epithelium, continuous with that of the conjunctiva; (2) the

* *Atlas of the Eye*, Clarendon Press, Oxford, 1912.

substantia propria; (3) the posterior elastic lamina; and (4) the endothelium of the anterior chamber.

The *corneal epithelium* covers the front of the cornea and consists of several layers of cells. The cells of the deepest layer are columnar; then follow two or three layers of polyhedral cells, the majority of which are prickle-cells similar to those found in the stratum mucosum of the cuticle.

FIG. 878.—A vertical section of the human cornea from near its margin. (Waldeyer.) Magnified.



1. Epithelium. 2. Anterior elastic lamina. 3. Substantia propria. 4. Posterior elastic lamina. 5. Endothelium of the anterior chamber. a. Oblique fibres in the anterior layer of the substantia propria. b. Lamellæ the fibres of which are cut across, producing a dotted appearance. c. Corneal corpuscles appearing fusiform in section. d. Lamellæ the fibres of which are cut longitudinally. e. Transition to the sclera, with more distinct fibrillation, and surmounted by a thicker epithelium. f. Small blood-vessels cut across near the margin of the cornea.

Lastly, there are three or four layers of squamous cells, with flattened nuclei.

The *substantia propria* is fibrous, tough, unyielding, and perfectly transparent. It is composed of about sixty flattened, superimposed lamellæ. These lamellæ are made up of bundles of modified connective tissue, the fibres of which are continuous with those of the sclera. The fibres of each lamina are for the most part parallel with one another, but at right angles to those of adjacent lamellæ. Fibres, however, frequently pass from one lamella to the next.

Between the lamellæ is a small amount of ground-substance, in which are spaces, the *corneal spaces*. These are stellate in shape and communicate with one another by numerous offsets. Each contains a cell, the *corneal corpuscle*, resembling in form the space in which it is lodged, but not entirely filling it.

The layer immediately beneath the corneal epithelium presents certain characteristics which have led some anatomists to regard it as a distinct membrane, and it has been named the *anterior elastic lamina*. It differs, however, from the posterior elastic lamina in showing evidence of fibrillar structure, and in not having the same tendency to curl inwards, or to undergo

fracture, when detached from the other layers of the cornea. It consists of extremely closely interwoven fibrils, similar to those found in the substantia propria, but contains no corneal corpuscles. It may be regarded as a condensed part of the substantia propria.

The *posterior elastic lamina* covers the posterior surface of the substantia propria, and is an elastic, transparent homogeneous membrane, of extreme thinness, which is not rendered opaque by water, alcohol, or acids. When stripped from the substantia propria it curls up, or rolls upon itself, with the attached surface innermost.

At the margin of the cornea the posterior elastic lamina breaks up into fibres which form the trabecular tissue on the inner wall of the sinus venosus scleræ (p. 952); the spaces between the trabeculæ are termed the *spaces of the angle of the iris* (spaces of Fontana); they communicate with the sinus venosus scleræ and with the anterior chamber at the filtration angle. Some of the fibres of this trabecular tissue are continued into the substance of the iris, forming the *pectinate ligament of the iris*; while others are connected with the fore part of the sclera and choroid.

The *endothelium of the anterior chamber* covers the posterior surface of the posterior elastic lamina, is reflected on to the front of the iris, and also lines the spaces of the angle of the iris; it consists of a layer of polygonal, flattened, nucleated cells.

Vessels and Nerves.—The cornea is a non-vascular structure, the capillary vessels of the conjunctiva and sclera ending in loops at its circumference. Lymphatic vessels have not yet been demonstrated in it, but are represented by the channels in which the bundles of nerves run; these channels are lined by an endothelium. The *nerves* are numerous and are derived from the ciliary nerves. Around the periphery of the cornea they form an *annular plexus*, from which fibres enter the substantia propria. They lose their medullary sheaths and ramify throughout the substantia propria in a delicate network, and their terminal filaments form a firm and closer plexus on the surface of the cornea proper, beneath the epithelium. This is termed the *subepithelial plexus*, and from it fibrils are given off which ramify between the epithelial cells, forming an *intra-epithelial plexus*.

II. THE VASCULAR TUNIC (figs. 874, 875, 876)

The vascular tunic of the eye is formed from behind forwards by the choroid, the ciliary body, and the iris.

The choroid covers the inner surface of the sclera, and extends as far forwards as the ora serrata of the retina. The ciliary body connects the choroid with the circumference of the iris. The iris is a circular diaphragm behind the cornea, and presents near its centre a rounded aperture, the *pupil*.

The choroid is a thin, highly vascular membrane, of a dark brown or chocolate colour, investing the posterior five-sixths of the globe; it is pierced behind by the optic nerve, and in this situation is firmly adherent to the sclera. It is thicker behind than in front. Its outer surface is loosely connected with the sclera by the lamina supra-chorioidea; its inner surface is attached to the pigmented layer of the retina.

Structure.—The choroid consists mainly of a dense capillary plexus, and of small arteries and veins carrying blood to, and returning it from, this plexus. On its external surface is a thin membrane, the *lamina supra-chorioidea*, composed of delicate non-vascular lamellæ, each lamella consisting of a network of fine elastic fibres among which are branched pigment-cells. The spaces between the lamellæ are lined by endothelium, and open freely into the perichoroidal lymph-space, which, in its turn, communicates with the periscleral space at the points where the vessels and nerves are transmitted through the sclera.

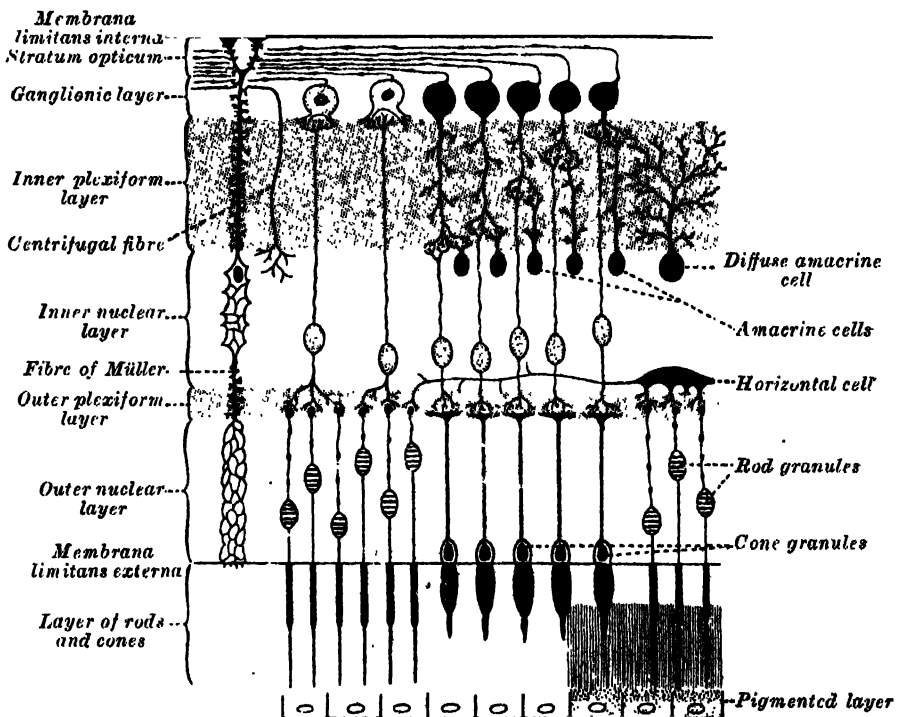
FIG. 874.—The choroid and iris. (Enlarged.)



1. The *stratum opticum* or *layer of nerve-fibres* is formed by the expansion of the fibres of the optic nerve; it is thickest near the *porus opticus*, gradually diminishing towards the *ora serrata*. As the nerve-fibres pass through the *lamina cribrosa sclerae*, they lose their medullary sheaths and are continued onwards through the chorioid and retina as simple axis-cylinders. When they reach the internal surface of the retina they radiate from their point of entrance over this surface, grouped in bundles which communicate with one another and form an intricate network. Most of the types are centripetal, and are the continuations of the axis-cylinder processes of the cells of the ganglionic layer, but a few are centrifugal; these originate in the brain and ramify in the inner plexiform and inner nuclear layers of the retina, where they end in enlarged extremities.

2. The *ganglionic layer* consists of a single layer of large nerve-cells, except in the *macula lutea*, where there are several strata. The cells are somewhat flask-shaped, the rounded internal surface of each resting on the *stratum opticum*, and

FIG. 884.—A plan of the retinal neurons. (After Ramón y Cajal.)



sending off an axon which is prolonged into it. From the opposite end numerous dendrites extend into the inner plexiform layer, where they form flattened arborisations at different levels. The ganglion-cells vary much in size, and the dendrites of the smaller ones as a rule arborise in the inner plexiform layer as soon as they enter it; while those of the larger cells ramify close to the inner nuclear layer.

3. The *inner plexiform layer* is made up of a dense reticulum of minute fibrils formed by the interlacement of the dendrites of the ganglion-cells with the processes of the cells of the inner nuclear layer; within this reticulum a few branched cells are imbedded.

4. The *inner nuclear layer* is made up of a number of closely packed cells, of which there are three varieties, viz. bipolar cells, horizontal cells, and amacrine cells.

The *bipolar cells*, by far the most numerous, are round or oval in shape, and each is prolonged into an inner and an outer process. The bipolar cells are divisible into rod-bipolars and cone-bipolars. The inner processes of the *rod-bipolars* run through the inner plexiform layer and arborise around the outer parts of the cell-bodies of the ganglionic layer; their outer processes end in the outer plexiform

layer in tufts of fibrils around the button-like ends of the inner processes of the rod-granules. The inner processes of the *cone-bipolars* ramify in the inner plexiform layer in contact with the dendrites of the ganglionic cells.

The *horizontal cells* lie in the outer part of the inner nuclear layer and possess somewhat flattened cell-bodies. Their dendrites divide into numerous branches in the outer plexiform layer, while their axons run horizontally for some distance and finally ramify in the same layer.

The *amacrine cells* are placed in the inner part of the inner nuclear layer, and were so named under the supposition that they possessed no axons. It is now known that some, at least, possess axons. Their dendrites undergo extensive ramification in the inner plexiform layer.

5. The *outer plexiform layer* is much thinner than the inner; but, like it, consists of a dense network of minute fibrils derived from the processes of the horizontal cells, and the outer processes of the rod- and cone-bipolar cells of the preceding layer, which arborise around the enlarged ends of the rod-fibres and the branched foot-plates of the cone-fibres.

6. The *outer nuclear layer*.—Like the inner nuclear layer, this contains several strata of oval cells; they are of two kinds, viz. rod-granules and cone-granules, the former being connected with the rods, the latter with the cones, of the next layer. The *rod-granules* are much the more numerous, and are placed at different levels throughout the layer. Their nuclei present in some animals a cross-striped appearance, and a fine process is prolonged from either extremity of each cell: the outer process is continuous with a single rod of the layer of rods and cones; the inner process ends in the outer plexiform layer in an enlarged extremity, and is imbedded in the tuft into which the outer processes of the rod-bipolar cells break up; in its course it presents numerous varicosities. The *cone-granules*, fewer in number than the rod-granules, are placed close to the *membrana limitans externa*, through which they are continuous with the cones of the layer of rods and cones. Each contains a spheroidal nucleus which almost completely fills the granule. From the inner extremity of each cone-granule a thick process passes into the outer plexiform layer, and there expands into a pyramidal enlargement or foot-plate, from which are given off numerous fine fibrils that come in contact with the outer processes of the cone-bipolars.

7. The *layer of rods and cones*.—The elements composing this layer are of two kinds, *rods* and *cones*, the former being much more numerous than the latter except in the macula lutea. The *rods* are cylindrical, of nearly uniform thickness, and are arranged perpendicularly to the surface. Each rod consists of two segments, an outer and an inner, of about equal lengths. The segments differ from each other as regards refraction and in their behaviour towards colouring reagents; the inner segment is stained by carmine, iodine, &c.; the outer segment is not stained by these reagents, but is coloured yellowish-brown by osmic acid. The outer segment is marked by transverse striæ, and tends to break up into a number of thin discs superimposed on one another; it also exhibits faint longitudinal markings. The inner part of the inner segment is indistinctly granular; the outer part presents a longitudinal striation, being composed of fine, highly refracting fibrils. The visual purple or rhodopsin is found only in the outer segments of the rods.

The *cones* are conical, their broad ends resting upon the *membrana limitans externa*, the narrow-pointed extremities being turned to the chorioid. Like the rods, each is made up of two segments, outer and inner; the outer segment is a short conical process, which, like the outer segment of a rod, exhibits transverse striæ. The inner segment resembles the inner segment of a rod in structure, presenting an outer striated and an inner granular part, but differs from it in size and shape, being flask-shaped. The optical characters of the two portions are identical with those of the rods.

Supporting framework of the retina.—The nervous layers of the retina are connected together by a supporting framework, formed by the *sustentacular fibres of Müller*; these fibres pass through all the nervous layers, except that of the rods and cones. Each fibre begins on the inner surface of the retina by an expanded, often forked, base, which sometimes contains a spheroidal body, staining deeply with hæmatoxylin; the edges of the bases of adjoining fibres are united to form the *membrana limitans interna*. As the fibres pass through the nerve-fibre and ganglionic layers they send off a few lateral branches; in the inner nuclear layer they give off numerous lateral processes for the support of the bipolar cells, while in the

outer nuclear layer they form a network around the rod- and cone-fibrils, and unite to form the *membrana limitans externa* at the bases of the rods and cones. At the level of the inner nuclear layer each sustentacular fibre contains a clear oval nucleus.

Structure of the macula lutea and fovea centralis.—At the fovea centralis there are no rods, and the cones are longer and thinner than in other parts of the retina. The nerve-fibre layer disappears at the margin of the fovea, and the other retinal layers are extremely thin. The pigment-cells are large and well-marked. At the circumference of the fovea the retina rapidly increases in thickness, so that this part of the macula lutea has a greater depth than any other part of the retina. All the layers are involved in this increase, but especially the ganglionic layer, in which the cells are six to eight deep. The yellow colour of the macula seems to imbue all the layers except that of the rods and cones; it is deepest towards the centre of the macula, and does not appear to be due to pigment-cells, but simply to a staining of the constituent parts.

At the *ora serrata* the nervous layers of the retina end abruptly, and the retina is continued onwards as a single layer of columnar cells along with the pigmented layer. This double layer is known as the *pars ciliaris retinae*, and can be traced forwards from the ciliary processes on to the back of the iris, where it is termed the *pars iridica retinae* or *uvea*.

The *arteria centralis retinae* (fig. 881) and its accompanying vein pierce the lower and medial aspect of the optic nerve, and enter the bulb of the eye through the porus opticus. The artery immediately bifurcates into an upper and a lower branch, and each of these again divides into a medial or nasal and a lateral or temporal branch, which at first run between the hyaloid membrane and the nervous layer; but they soon enter the latter, and pass forwards, dividing dichotomously. From these branches a minute capillary plexus is given off, which does not extend beyond the inner nuclear layer. The macula receives two small branches (superior and inferior macular arteries) from the temporal branches, and small twigs directly from the central artery; these do not, however, reach as far as the fovea centralis, which has no blood-vessels. The branches of the *arteria centralis retinae* do not anastomose with each other—in other words, they are terminal arteries. In the fœtus, a small vessel, the *arteria hyaloidea*, passes forwards as a continuation of the *arteria centralis retinae* through the vitreous humour to the posterior surface of the capsule of the lens.

REFRACTING MEDIA

The refracting media are three, viz. :

Aqueous humour.	Vitreous body.	Crystalline lens.
-----------------	----------------	-------------------

I. AQUEOUS HUMOUR

The aqueous humour fills the anterior and posterior chambers of the eyeball (p. 958). It is small in quantity, has an alkaline reaction, and is mainly a dilute watery solution of chloride of sodium. It is secreted by the ciliary processes into the posterior chamber and escapes from the filtration angle of the anterior chamber through the spaces of the angle of the iris (spaces of Fontana) and sinus venosus sclerae (canal of Schlemm) into the anterior ciliary veins.

II. VITREOUS BODY

The vitreous body occupies about four-fifths of the bulb of the eye. It fills the concavity of the retina, and is hollowed in front, forming a deep concavity, the *hyaloid fossa*, for the reception of the lens. It is transparent, of the consistence of thin jelly, and is enclosed in a delicate transparent membrane, the *hyaloid membrane*. It has been supposed by Hannover, that from the surface of the hyaloid membrane numerous thin lamellæ are prolonged inwards in a radiating manner, forming spaces in which the jelly is contained. In the adult, these lamellæ cannot be detected even after careful microscopical examination in the fresh state, but in preparations hardened in weak chromic acid it is possible to make out a distinct lamellation at the periphery of the vitreous body. Running forwards through the vitreous body from the entrance of the optic nerve to the posterior surface of the lens, is a canal, the *hyaloid canal*, filled with lymph and lined by a prolongation of the hyaloid membrane.

In the embryonic vitreous body this canal conveyed the arteria hyaloidea from the central artery of the retina to the back of the lens.

The fluid from the vitreous body is nearly pure water ; it contains, however, some salts, and a little albumin.

The *hyaloid membrane* envelops the vitreous body. The portion in front of the ora serrata is thickened by the accession of radial fibres and is termed the *zonula ciliaris* or *zonule of Zinn*. Here it presents a series of radially arranged furrows, in which the ciliary processes are accommodated and to which they adhere, as is shown by the fact that when they are removed some of their pigment remains attached to the zonula. The zonula ciliaris splits into two layers, one of which is thin and lines the hyaloid fossa of the vitreous body ; the other, named the *suspensory ligament of the lens*, is thicker, and passes over the ciliary body to be attached to the capsule of the lens a short distance in front of its equator. Scattered and delicate fibres are also attached to the region of the equator itself. This ligament retains the lens in position, and is relaxed by the contraction of the meridional fibres of the Ciliaris muscle, so that the lens is allowed to become more convex. Behind the suspensory ligament there is a sacculated canal, the *spatia zonularia* or *canal of Petit*, which encircles the equator of the lens ; it can be easily inflated through a fine blowpipe inserted under the suspensory ligament.

No blood-vessels penetrate the vitreous body ; so that its nutrition must be carried on by the vessels of the retina and ciliary processes, situated upon its exterior.

III. CRYSTALLINE LENS

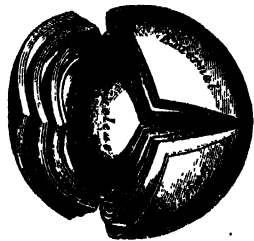
The **crystalline lens**, enclosed in its capsule, is situated immediately behind the iris, in front of the vitreous body, and is encircled by the ciliary processes, which slightly overlap its margin.

The *capsule of the lens* is a transparent, structureless membrane which closely surrounds the lens, and is thicker in front than behind. It is brittle but highly elastic, and when ruptured the edges roll up with the outer surface innermost. The lens rests, behind, in the hyaloid fossa on the fore-part of the vitreous body ; in front, it is in contact with the free border of the iris, but recedes from it at the circumference, thus forming the posterior chamber of the eye ; it is retained in its position chiefly by the suspensory ligament already described.

The *lens* is a transparent, biconvex body, the convexity of its anterior being less than that of its posterior surface. The central points of these surfaces are termed respectively the *anterior* and *posterior poles* ; a line connecting the poles constitutes the *axis* of the lens, while the marginal circumference is termed the *equator*.

Structure.—The lens is made up of soft cortical substance and a firm, central part, the nucleus (fig. 885). Faint lines (*radii lentis*) radiate from the poles to the equator. In the adult there may be six or more of these lines, but in the fœtus there are only three, and these diverge from each other at angles of 120° (fig. 886) ; on the anterior surface one line ascends vertically and the other two diverge downwards ; on the posterior surface one ray descends vertically and the other two diverge upwards. They correspond with the free edges of an equal number of septa composed of an amorphous substance, which dip into the substance of the lens. When the lens has been hardened it is seen to consist of a series of concentrically arranged laminae, each of which is interrupted at the septa referred to. Each lamina is built up of a number of ribbon-like lens-fibres, the edges of which are more or less serrated—the serrations fitting between those of neighbouring fibres, while the ends of the fibres come into apposition at the septa. The fibres run in a curved manner from the septa on the anterior surface to those on the posterior surface. No fibres pass from pole to pole ; they are arranged in such a way that those which begin near the pole on one surface of the lens end

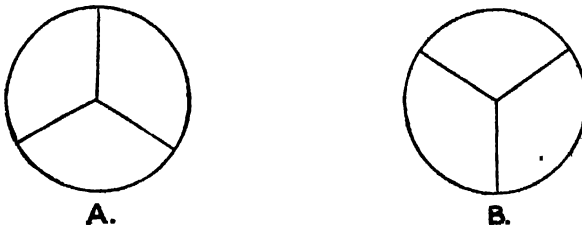
FIG. 885.—The crystalline lens, hardened and divided. (Enlarged.)



near the peripheral extremity of the plane on the other, and vice versa. The fibres of the outer layers of the lens are nucleated, and together form a nuclear layer, most distinct towards the equator. The anterior surface of the lens is covered by a layer of transparent, nucleated columnar epithelium. At the equator the cells become elongated, and their gradual transition into lens-fibres can be traced (fig. 888).

In the fetus, the lens is nearly spherical, and has a slightly reddish tint; it is soft, and breaks down readily on the slightest pressure. A small branch from the arteria centralis retinæ runs forwards, as already mentioned, through the

FIG. 886.—A diagram to show the direction and arrangement of the radiating lines on the front and back of the foetal lens. A. On the front. B. On the back.



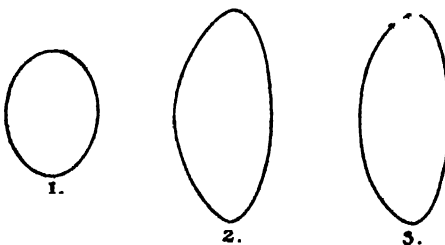
vitreous body to the posterior part of the capsule of the lens, where its branches radiate and form a plexiform network which covers the posterior surface of the capsule, and they are continuous round the margin of the capsule with the vessels of the pupillary membrane and with those of the iris. *In the adult*, the lens is colourless, transparent, firm in texture, and devoid of vessels. *In old age*, it becomes flattened on both surfaces, slightly opaque, of an amber tint, and increased in density (fig. 887).

Vessels and Nerves.—The arteries of the bulb of the eye are the long, short, and anterior ciliary arteries, and the arteria centralis retinæ. They have already been described (p. 597).

The ciliary veins are seen on the outer surface of the chorioid, and are named, from their arrangement, the *venæ vorticose*; they converge to four or five equidistant trunks which pierce the sclera midway between the sclero-corneal junction and the porus opticus. Another set of veins accompanies the anterior ciliary arteries. All these veins open into the ophthalmic veins.

The ciliary nerves are derived from the nasociliary nerve and from the ciliary ganglion.

FIG. 887.—A profile view of the lens at different periods of life.



1. In the fetus. 2. In adult life. 3. In old age:

continuous with the epithelial covering of the rest of the body, so that its lesions resemble those of the epidermis; (2) the cornea proper, derived from the mesoderm, and associated in its diseases with the fibrovascular structures of the body; and (3) the posterior elastic lamina with its endothelium, also derived from the mesoderm and having the characters of a serous membrane, so that inflammation of it resembles inflammation of the serous and synovial membranes of the body.

The cornea contains no blood-vessels except at its periphery, where numerous delicate loops, derived from the anterior ciliary arteries, may be demonstrated on its anterior surface. The rest of the cornea is nourished by lymph, which gains access to the proper substance of the cornea and the posterior layer through the spaces of the angle of the iris. This lack of a direct blood-supply renders the cornea very apt to inflame in the cachectic and ill-nourished. In cases of *granular lids*, there is a peculiar affection of the cornea, called *pannus*, in which the anterior layers of the cornea become vascularised, and a rich network of blood-vessels may be seen upon it; and in *interstitial keratitis* new vessels extend into the cornea, giving it a pinkish hue to which the term 'salmon patch' is

Applied Anatomy.—From a surgical point of view the cornea may be regarded as consisting of three layers: (1) an external epithelial layer, developed from the ectoderm, and

applied. In cases of glaucoma the ciliary nerves may be pressed upon as they course between the chorioid and sclera, the cornea becoming anæsthetic.

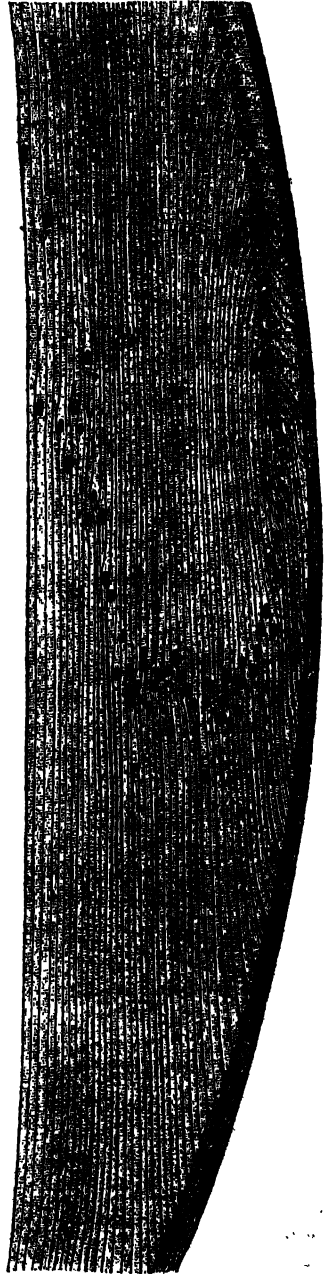
The sclera has very few blood-vessels and nerves. As the blood-vessels approach the corneal margin the arrangement is peculiar. Some branches pass through the sclera to the ciliary body; others become superficial and lie in the episcleral tissue, and form arches by anastomosing with each other some little distance behind the corneal margin. From these arches numerous straight vessels are given off, which run forwards to the cornea, forming its marginal plexus. In inflammation of the sclera and episcleral tissue these vessels become conspicuous, and form a pinkish zone of straight vessels radiating from the corneal margin, commonly known as the *zone of ciliary injection*. In inflammation of the iris and ciliary body this zone is present, since the sclera speedily becomes involved when these structures are inflamed. But in inflammation of the cornea the sclera is seldom much affected, though the two are structurally continuous. This would appear to be due to the fact, that the nutrition of the cornea is derived from a different source than that of the sclera. The sclera may be ruptured without any laceration of the conjunctiva, and the rupture usually occurs near the corneal margin. It may be complicated with lesions of adjacent parts—laceration of the chorioid, retina, iris, or suspensory ligament of the lens—and is then often attended with hæmorrhage into the anterior chamber, which masks the nature of the injury. In some cases the lens has escaped through the rent in the sclera. Wounds of the sclera are always dangerous, and are often followed by inflammation, suppuration, and by sympathetic ophthalmia.

One of the functions of the chorioid is to provide nutrition for the retina, and to convey vessels and nerves to the ciliary body and iris. Inflammation of the chorioid is therefore followed by grave disturbances in the nutrition of the retina, and is attended with early interference with vision. Its diseases bear a considerable analogy to those which affect the skin, and it is one of the places from which melanotic sarcomata may grow. These tumours contain a large amount of pigment in their cells, and originate only in those parts where pigment is naturally present.

The iris may be absent, either in part or altogether, as a congenital condition, and in some instances the pupillary membrane may persist, though rarely as a complete structure. Again, the iris may be the seat of a malformation, termed *coloboma*, which consists in a deficiency or cleft, clearly due in a great number of cases to an arrest in development. In these cases the cleft is found at the lower aspect, extending directly downwards from the pupil, and the gap frequently extends through the chorioid to the porus opticus. Wounds of the iris, especially if complicated with injury to the ciliary body, may be followed by serious consequences. If septic matter is introduced, and a suppurative inflammation is set up, complete loss of vision may result; and, what is perhaps of greater consequence, similar inflammatory changes may be set up in the sound eye. The iris is abundantly supplied with blood-vessels and nerves, and is very prone to become inflamed, and when inflamed, in consequence of the intimate relationship

which exists between the vessels of the iris and chorioid, this latter tunic is very liable to participate in the inflammation. The iris is covered with epithelium, and partakes of the character of a serous membrane, and like these structures, is apt to pour out a plastic exudation when inflamed, and contract adhesions, either to the cornea in front (*synechia anterior*), or to the capsule of the lens behind (*synechia posterior*). In iritis the lens may become involved, and the condition known as secondary cataract may be set up.

FIG. 888.—A section through the margin of the lens, showing the transition of the epithelium into the lens-fibres. (Babuchin.)



The retina, with the exception of its pigment layer and its vessels, is perfectly transparent. In retinitis there is more or less dense opacity of its structure, and not infrequently extravasations of blood into its substance. Hemorrhages may also take place into the retina, from rupture of a blood-vessel without inflammation. The retina may become detached from effusion of serum between it and the chorioid, or by blows on the eyeball; but detachment of the retina may occur without apparent cause in progressive myopia. Glioma, a form of sarcoma, is occasionally met with in the retina.

The lens has no blood-vessels, nerves, or connective tissue in its structure, and therefore is not subject to those morbid changes to which tissues containing these structures are liable. Opacities may occur from injury, senile changes, or malnutrition. These opacities give rise to *cataract*, of which the senile variety is the most common. They vary as to the part of the lens in which the opacity commences, and are classified accordingly, as nuclear, cortical, lamellar, anterior and posterior polar. Senile changes may take place in the lens, impairing its elasticity and rendering it harder than in youth, so that it loses its power of altering its curvature to suit the requirements of near vision. This condition is known as *presbyopia*. The lens may be dislocated or displaced by blows upon the eyeball; and its relations to surrounding structures altered by adhesions or the pressure of new growths.

There are two particular regions of the eye which require special notice: one of these is known as the 'filtration angle,' and the other as the 'dangerous area.' The *filtration angle* is the circumcorneal zone immediately in front of the iris. Here are situated the spaces of the angle of the iris, which communicate with the sinus venosus scleræ through which the chief transudation of fluid from the eye is believed to take place. If any obstruction to this transudation occur, increased intra-ocular tension is set up, and the disease known as *glaucoma* results. The *dangerous area of the eye* is the region in the neighbourhood of the ciliary body, and wounds or injuries in this situation are peculiarly dangerous; for inflammation of the ciliary body is apt to spread to many of the other structures of the eye, especially to the iris and chorioid, which are intimately connected with it by nervous and vascular supplies.

ACCESSORY ORGANS OF THE EYE

The accessory organs of the eye include the ocular muscles, the fasciæ, the eyebrows, the eyelids, the conjunctiva, and the lacrimal apparatus.

OCULAR MUSCLES

The ocular muscles are the:

Levator palpebræ superioris.	Rectus medialis.
Rectus superior.	Rectus lateralis.
Rectus inferior.	Obliquus superior.
Obliquus inferior.	

The *Levator palpebræ superioris* (figs. 889, 890) is thin, flat, and triangular in shape. It arises from the under surface of the small wing of the sphenoid, above and in front of the optic foramen, from which it is separated by the origin of the Rectus superior. At its origin, it is narrow and tendinous, but soon becomes broad and fleshy, the medial margin of the muscle being almost straight, while the lateral margin curves towards the lateral canthus. The muscle ends anteriorly in a wide aponeurosis which splits into two lamellæ. The uppermost fibres of the superficial lamella blend with the upper part of the orbital septum; the lowermost fibres are attached to the anterior surface of the tarsus, while the intermediate fibres radiate and pass through the overlying Orbicularis oculi to the skin of the upper eyelid. The deep lamella consists of non-striped muscular fibres and is known as *Müller's muscle**; it is attached directly to the upper margin of the superior tarsus and is covered by conjunctiva on its inferior surface. The space between the superficial and deep lamellæ is termed the *preseptal space* (fig. 890).

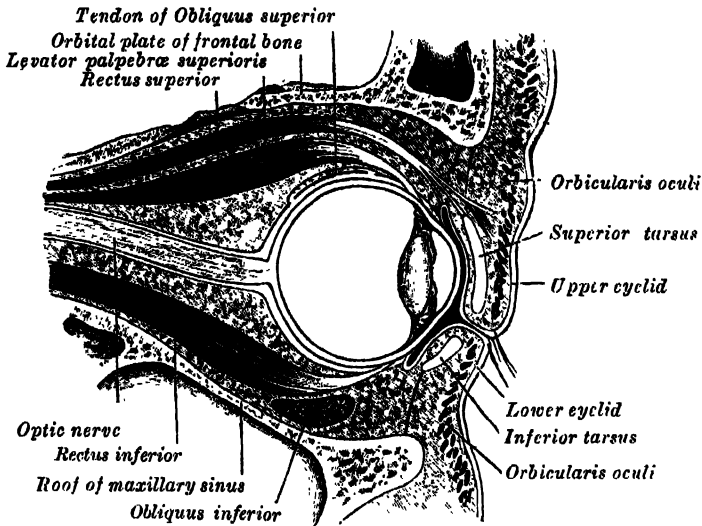
The fascial sheaths of the Levator palpebræ superioris and Rectus superior fuse. Where the two muscles separate to reach their insertions, the fascia between them forms a thick mass which is fixed to the superior conjunctival fornix and is described as an additional insertion of the Levator palpebræ superioris. When traced laterally the

* H. Müller also described a layer of non-striped muscle in the lower eyelid, where it unites the inferior tarsus to the Obliquus inferior.

OCULAR MUSCLES

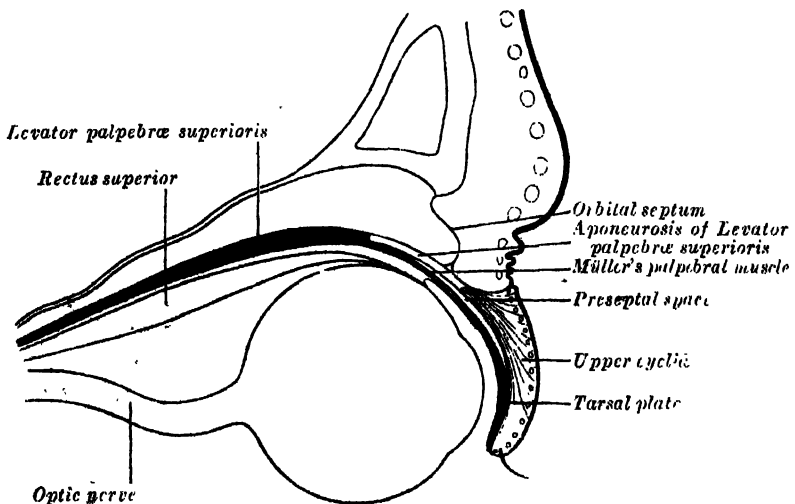
aponeurosis of the Levator palpebræ superioris passes between the upper and lower parts of the lacrimal gland, and is fixed to a tubercle on the zygomatic bone, just within the orbital margin (p. 234). Deep to this attachment is that of the lateral palpebral raphe

FIG. 889.—A sagittal section of the right orbital cavity.



which fixes the tarsal plates to the same tubercle. When traced medially the aponeurosis loses its tendinous nature as it passes over and comes into close contact with the reflected tendon of the Obliquus superior, whence it can be followed with difficulty towards the medial palpebral ligament in the form of loose strands of connective tissue. When the

FIG. 890.—A diagram of a sagittal section of the orbit to show the insertions of the Levator palpebræ superioris. (After Whitnall.)

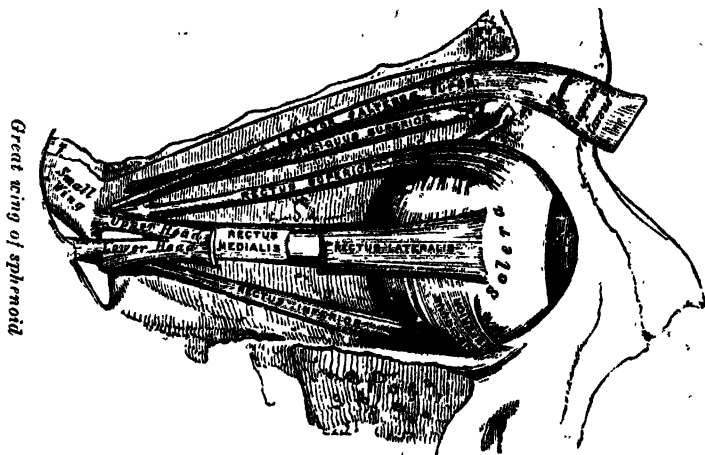


* Levator palpebræ contracts, the lateral and medial parts of the aponeurosis are stretched and check the action of the muscle; the retraction of the upper eyelid is checked also by the orbital septum.*

* A. E. Whitnall, *Journal of Anatomy and Physiology*, vol. xiv., and *Ophthalmoscope*, May 1914.

The four Recti (fig. 891) arise from a fibrous ring (annulus tendineus communis) which surrounds the upper, medial, and lower margins of the optic foramen and encircles the optic nerve (fig. 892). The ring is completed by a tendinous bridge prolonged over the lower and medial part of the superior orbital fissure and attached to a tubercle on the margin of the great wing of the sphenoid bounding the fissure. Two specialised parts of this fibrous ring may be made out: a lower, the ligament or tendon of Zinn, which gives origin to the Rectus inferior, part of the Rectus medialis, and the lower head of origin of the Rectus lateralis; and an upper, sometimes termed the superior tendon of Lockwood, which gives origin to the Rectus superior, the rest of the Rectus medialis, and the upper head of the Rectus lateralis. Each muscle passes forward in the position implied by its name, to be inserted by a tendinous expansion into the sclera, about 6 mm. from the margin of the cornea. Between the two heads of the Rectus lateralis is a narrow interval, which transmits the two divisions of the oculomotor nerve, the nasociliary nerve, the abducent nerve, and the ophthalmic veins. Although these muscles present a common origin and are inserted in a similar manner into the sclera, there are certain

FIG. 891.—The muscles of the right orbit.



differences to be observed in them. The Rectus medialis is the broadest, the Rectus lateralis the longest, and the Rectus superior the thinnest and narrowest. The Rectus lateralis is inserted slightly further back than the Rectus medialis and Rectus superior.

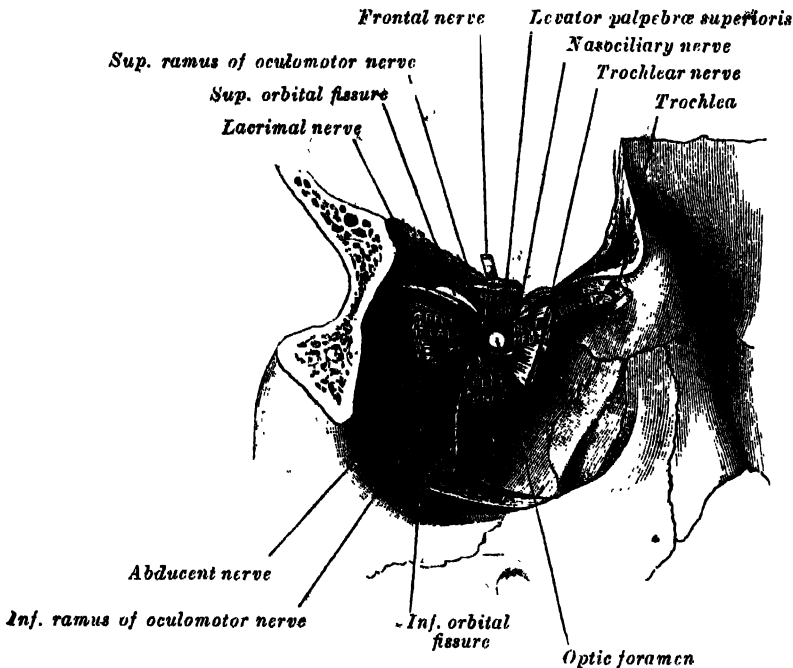
The Obliquus oculi superior is a fusiform muscle, placed at the upper and medial side of the orbit. It arises immediately above the optic foramen, above and medially to the origin of the Rectus superior, and, passing forwards, ends in a rounded tendon, which plays in a fibrocartilaginous ring or pulley attached to the fovea trochlearis of the frontal bone. The contiguous surfaces of the tendon and ring are lined by a delicate mucous sheath, and enclosed in a thin fibrous investment. After passing through the pulley the tendon is reflected backwards, lateralwards, and downwards beneath the Rectus superior, to the lateral part of the bulb of the eye, and is inserted into the sclera, behind the equator of the eyeball, and between the Rectus superior and Rectus lateralis.

The Obliquus oculi inferior is a thin, narrow muscle, placed near the anterior margin of the floor of the orbit. It arises from the orbital surface of the maxilla laterally to the lacrimal groove. Passing lateralwards, backwards, and upwards, at first between the Rectus inferior and the floor of the orbit, and then between the bulb of the eye and the Rectus lateralis, it is inserted into the lateral part of the sclera between the Rectus superior and Rectus lateralis, near to, but somewhat behind, the insertion of the Obliquus superior.

Nerves.—The Levator palpebræ superioris, the Obliquus inferior, and the Recti superior, inferior, and medialis are supplied by the oculomotor nerve; the Obliquus superior, by the trochlear nerve; the Rectus lateralis, by the abducent nerve.

Actions.—The Levator palpebræ raises the upper eyelid, and is the direct antagonist of the Orbicularis oculi. The four Recti are attached to the bulb of the eye in such a manner that, acting singly, they will turn its corneal surface either upwards, downwards, medialwards, or lateralwards, as expressed by their names. The movement produced by the Rectus superior or Rectus inferior is not quite a simple one, for inasmuch as each passes obliquely lateralwards and forwards to the bulb of the eye, the elevation or depression of the cornea is accompanied by a certain deviation medialwards, with a slight amount of rotation. These latter movements are corrected by the Obliqui, the Obliquus inferior correcting the medial deviation caused by the Rectus superior, and the Obliquus superior that caused by the Rectus inferior. The contraction of the Rectus lateralis or Rectus medialis, on the other hand, produces a purely horizontal movement. If any two neighbouring Recti of

FIG. 892.—A dissection showing the origins of the right ocular muscles, and the nerves entering the orbit through the superior orbital fissure.



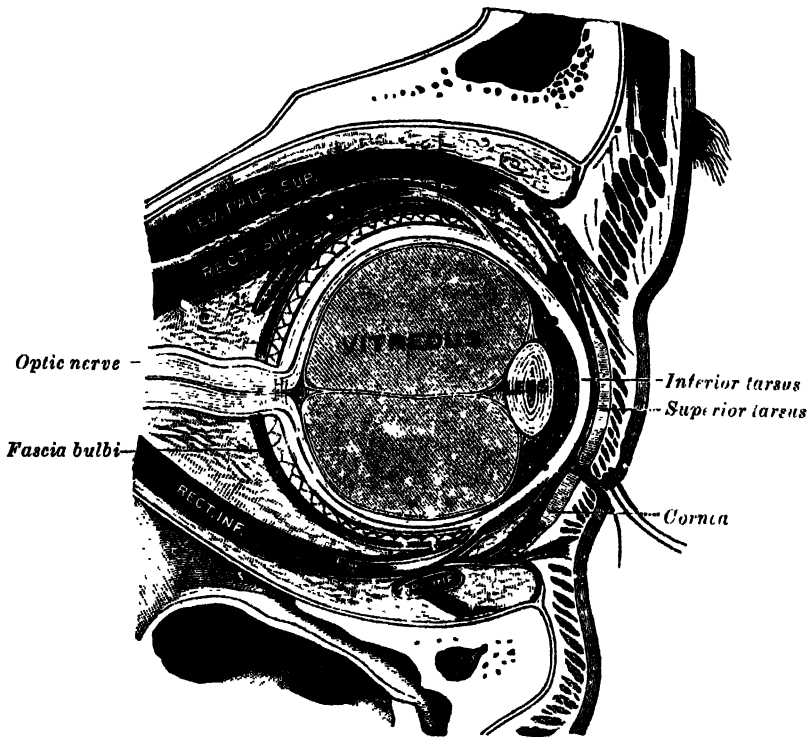
one eye act together they carry the globe of the eye in the diagonal of these directions, viz. upwards and medialwards, upwards and lateralwards, downwards and medialwards, or downwards and lateralwards. Sometimes the corresponding Recti of the two eyes act in unison, and at other times the opposite Recti act together. Thus, in turning the eyes to the right, the Rectus lateralis of the right eye will act in unison with the Rectus medialis of the left eye; but if both eyes are directed to an object in the middle line at a short distance, the two Recti mediales will act in unison. The movement of circumduction, as in looking round a room, is performed by the successive actions of the four Recti. The Obliqui rotate the bulb of the eye on its anteroposterior axis, the superior directing the cornea downwards and lateralwards, and the inferior directing it upwards and lateralwards; these movements are required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder, in order that the picture may fall in all respects on the same part of the retina of either eye.

A layer of non-striped muscle, the *Orbitalis muscle* of H. Müller, bridges across the inferior orbital fissure.*

* The *Orbitalis muscle* of Müller must not be confused with the palpebral non-striped muscle described by him. In the upper eyelid this unites the superior tarsus to the tendon of the Levator palpebræ superioris; in the lower eyelid it connects the inferior tarsus with the Obliquus inferior (see p. 969).

The **fascia bulbi** (capsule of Tenon) (fig. 893) is a thin membrane which envelops the bulb of the eye from the optic nerve to the ciliary region, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is separated from the outer surface of the sclera by the *periscleral lymph-space*; this lymph-space is continuous with the subdural and subarachnoid cavities, and is traversed by delicate bands of connective tissue which extend between the fascia and the sclera. The fascia is perforated behind by the ciliary vessels and nerves, and fuses with the sheath of the optic nerve and with the sclera around the entrance of the optic nerve. In front it blends with the ocular conjunctiva, and with it is attached to the ciliary region of the eyeball. It is perforated by the tendons of the ocular muscles,

FIG. 893.—A sagittal section of the right eye, showing the fascia bulbi.
(Semi-diagrammatic.) (Testut.)



and is reflected backwards on each as a tubular sheath. The sheath of the Obliquus superior is carried as far as the fibrous pulley of that muscle; that on the Obliquus inferior reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the Recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the Rectus superior blends with the tendon of the Levator palpebrae superioris; that of the Rectus inferior is attached to the inferior tarsus. The expansions from the sheath of the Recti medialis and lateralis are strong, especially that from the latter muscle, and are attached to the lacrimal and zygomatic bones respectively. As they probably check the actions of these two Recti they have been named the *medial and lateral check ligaments*. Lookwood* described a thickening of the lower part of the fascia bulbi, which he named the *suspensory ligament of the eye*; it is slung like a hammock below the eyeball, being expanded in the centre, and narrow at its extremities, which are attached to the zygomatic and lacrimal bones respectively.

* *Journal of Anatomy and Physiology*, vol. xx.

The orbital fascia forms the periosteum of the orbit, but is loosely connected to the bones. Behind, it is united with the dura mater and with the sheath of the optic nerve. In front, it is connected with the periosteum at the margin of the orbit, and sends off a stratum which assists in forming the orbital septum. From it two processes are given off: one to enclose the lacrimal gland, the other to hold the pulley of the Obliquus superior in position.

Applied Anatomy.—The positions and exact areas of insertion of the tendons of the Recti medialis and lateralis into the bulb of the eye should be carefully examined from the front, as the surgeon is often required to divide one or other of the muscles for the cure of strabismus. In convergent strabismus, which is the more common form of the disease, the eye is turned medialwards, which may require the division of the Rectus medialis. In the divergent form, which is more rare, the eye is turned lateralwards, the Rectus lateralis being especially implicated. If the deformity produced in either case be marked, it may be remedied by division of one or the other muscle. The operation is thus performed: the lids are to be well separated; the eyeball is rotated lateralwards or medialwards, and the conjunctiva raised by a pair of forceps, and incised immediately beneath the lower border of the tendon of the muscle to be divided, a little behind its insertion into the sclera; the submucous areolar tissue is then divided, and into the small aperture thus made, a blunt hook is passed upwards between the muscle and the bulb, and the tendon of the muscle divided by a pair of blunt-pointed scissors passed between the hook and the bulb.

The converse operation is that of *advancement*, in which either the Rectus medialis or Rectus lateralis (depending on the form of strabismus) is shortened. The muscle is exposed in a similar manner; its tendon is divided, and sutured to the globe of the eye in front of its previous site of attachment.

Removal of the eyeball is effected by dividing the conjunctiva all round with scissors at its attachment to the cornea, after which each ocular muscle in turn is picked up on a blunt hook and divided close to the sclera. The optic nerve is then divided with curved scissors passed to the back of the orbit; it should be remembered that the perineural sheaths from the meninges are opened by this manœuvre.

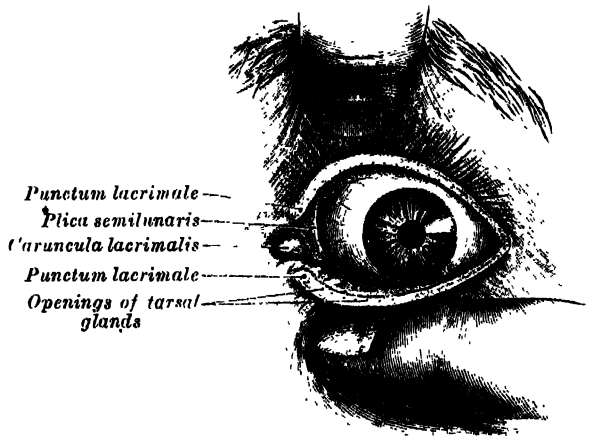
Exophthalmos, or abnormal protrusion of the eyeball, is usually bilateral. It is almost always present in exophthalmic goitre or Graves' disease, in which it is due to abnormal stimulation of the cervical sympathetic nerves producing spasm of Müller's muscle, which passes between the eyeball and the eyelids. Less often it results from venous congestion of the orbital veins due to thrombosis of the cavernous sinuses. Unilateral exophthalmos is rare, and is caused by orbital cellulitis, periostitis, or new growth, or by traumatic arterial or arteriovenous aneurysm of the carotid artery behind the orbit. Intermittent exophthalmos, occurring only when the head is depressed, is very rare, and is due to the presence of varicose veins in the orbit.

In hydrocephalus the eyeball may be forced down so low in the orbit, through depression of the orbital plate of the frontal bone by the accumulation of fluid within the brain, that the patient, usually an infant, loses his sight because the pupil comes to lie below the lower eyelid even when the eye is open.

The eyebrows are two arched eminences of skin, which surmount the orbits, and support numerous short, thick hairs directed obliquely on the surface. Fibres of the Orbicularis oculi, Corrugator, and Frontalis muscles are inserted into the skin of the eyebrows.

The eyelids or palpebræ are two thin, movable folds, placed in front of the eye, protecting it from injury by their closure. The upper eyelid is the larger and more movable, and is furnished with an elevator muscle, the Levator palpebræ superioris. When the eyelids are open, an elliptical space, the palpebral fissure (*rima palpebrarum*) is left between their margins, the angles

FIG. 894.—The front of the left eye with the eyelids separated to show the plica semilunaris, caruncula lacrimalis and puncta lacrimalia.

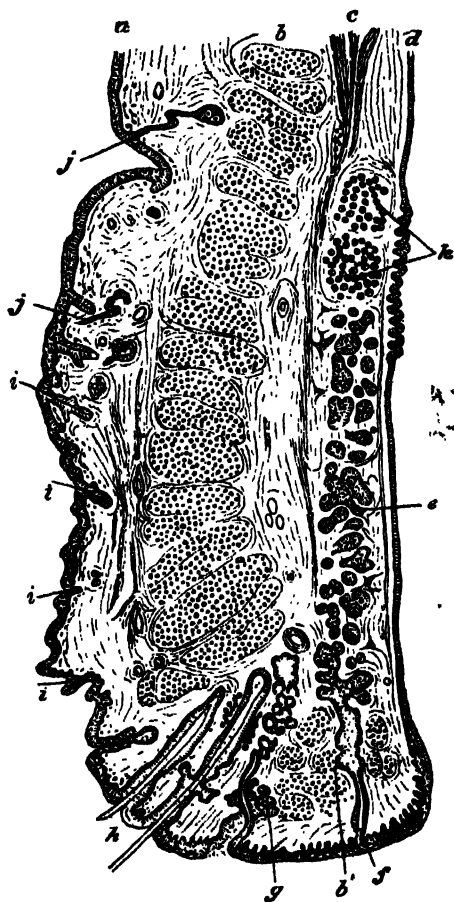


of which correspond to the junctions of the upper and lower eyelids, and are called the *palpebral commissures* or *canthi*.

The *lateral palpebral commissure* is more acute than the medial, and the eyelids here lie in close contact with the bulb of the eye: but the *medial palpebral commissure* is prolonged for a short distance towards the nose, and the two eyelids are separated by a triangular space, the *lacus lacrimalis* (fig. 894). At the basal angles of the lacus lacrimalis, on the margin of each eyelid, is a small conical elevation, the *lacrimal papilla*, the apex of which is pierced by a small orifice, the *punctum lacrimale*, the commencement of the lacrimal duct.

The *eyelashes* are attached to the free edges of the eyelids from the lateral palpebral commissure to the lacrimal papillæ. They are short, thick, curved

FIG. 895.—A sagittal section through the upper eyelid. (After Waldeyer.)



a. Skin. b. Orbicularis oculi. b'. Marginal fasciculus of Orbicularis (ciliary bundle). c. Levator palpebræ. d. Conjunctiva. e. Tarsal glands. f. Opening of tarsal gland. g. Sebaceous gland. h. Eyelashes. i. Small hairs of skin. j. Sweat-glands. k. Posterior tarsal glands.

hairs, arranged in double or triple rows: those of the upper eyelid, more numerous and longer than those of the lower, curve upwards; those of the lower eyelid curve downwards, so that the upper and lower eyelashes do not interlace in closing the lids. Near the attachment of the eyelashes are the openings of a number of glands, the *ciliary glands*, arranged in several rows close to the free margin of each lid; they are regarded as enlarged and modified sudoriferous glands.

Structure of the eyelids.—From without inwards, each eyelid consists of: skin, areolar tissue, fibres of the Orbicularis oculi, tarsus, orbital septum, tarsal glands and conjunctiva. The upper eyelid has, in addition, the aponeurosis of the Levator palpebræ superioris (fig. 895).

The *skin* is extremely thin, and continuous at the margins of the eyelids with the conjunctiva.

The *subcutaneous areolar tissue* is very lax and delicate, and seldom contains any fat.

The *palpebral fibres of the Orbicularis oculi* are thin, pale in colour, and parallel to the palpebral fissure.

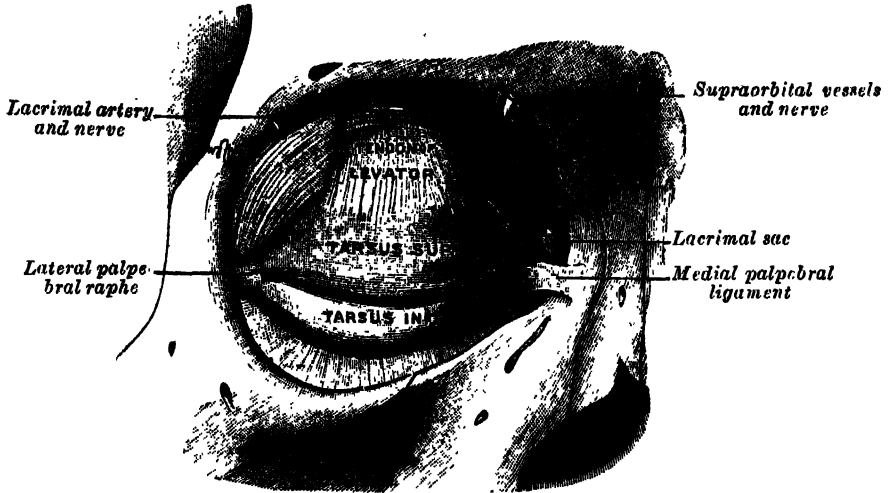
The *tarsi* (fig. 896) are two thin elongated plates of dense connective tissue, about 2.5 cm. in length; one is placed in each eyelid, and contributes to its form and support. The *superior tarsus*, the larger, is of a semilunar form, about 10 mm. in height at the centre, and gradually narrowing towards its extremities.

The lowest fibres of the superficial

lamella of the aponeurosis of the Levator palpebræ superioris are attached to the anterior surface, and the deep lamella of the same aponeurosis is inserted into the upper margin, of the superior tarsus. The *inferior tarsus*, the smaller, is thin, fairly uniform in breadth, and has a vertical diameter of about 5 mm. The free or ciliary margins of these plates are thick and straight. The attached or orbital margins are connected to the circumference of the orbit by the orbital septum. The lateral angles are attached to the zygomatic bone by the lateral palpebral raphe. The medial angles of the two plates end at the lacus lacrimalis, and are attached to the frontal process of the maxilla by the medial palpebral ligament (p. 429).

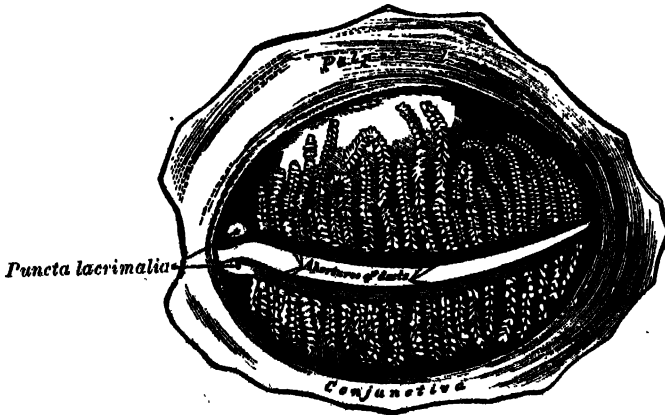
The *orbital septum* is a membranous sheet, attached to the edge of the orbit, where it is continuous with the periosteum. In the upper eyelid it blends with the aponeurosis of the Levator palpebræ superioris, and in the lower eyelid with the inferior tarsus. It is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp.

FIG. 896.—The tarsi and their ligaments. Front view. (Testut.)



The *tarsal glands* (Meibomian glands) (fig. 897) are situated near the inner surfaces of the eyelids, between the tarsi and conjunctiva, and may be distinctly seen through the latter on everting the eyelids, presenting an appearance like parallel strings of pearls. There are about thirty in the upper eyelid, and somewhat fewer in the lower. They are imbedded in grooves in the inner surfaces of the

FIG. 897.—The tarsal glands of the eyelids. Seen from within.



tarsi and correspond in length with the breadth of these plates; they are, consequently, longer in the upper than in the lower eyelid. Their ducts open on the free margins of the lids by minute foramina.

Structure.—The tarsal glands are modified sebaceous glands, each consisting of a single straight tube or follicle, with numerous small lateral diverticula. The tubes are supported by a basement membrane, and are lined at their mouths by stratified epithelium; the deeper parts of the tubes and the lateral offshoots are lined by a layer of polyhedral cells.

The *conjunctiva* is the mucous membrane of the eye. It lines the inner surfaces of the eyelids or palpebræ, and is reflected over the fore part of the sclera and the cornea.

The *palpebral portion* is thick, opaque, highly vascular, and has numerous subepithelial connective tissue papillæ, its deeper part containing a considerable amount of lymphoid tissue. At the margins of the lids it is continuous with the lining membranes of the ducts of the tarsal glands, and, through the lacrimal ducts, with the lining membrane of the lacrimal sac and nasolacrimal duct. At the lateral angle of the upper eyelid the ducts of the lacrimal gland open on its free surface; and at the medial angle it forms a semilunar fold, the *plica semilunaris*. The line of reflection of the conjunctiva from the upper eyelid on to the bulb of the eye is named the *superior fornix*, and that from the lower lid the *inferior fornix*; on account of the greater size of the upper eyelid the superior fornix appears to be situated further back than the inferior. Upon the *sclera* the conjunctiva is loosely connected to the bulb of the eye; it is thin, transparent, destitute of papillæ, and only slightly vascular. Upon the *cornea*, the conjunctiva consists only of epithelium, constituting the epithelium of the cornea, already described (p. 954). The epithelium of the palpebral conjunctiva is columnar, that of the corneal conjunctiva and the cornea is stratified squamous. *Lymphatics* arise in a delicate zone around the cornea, and run to the ocular conjunctiva.

In and near the fornices, but more plentiful in the upper than in the lower eyelid, a number of convoluted tubular glands open on the surface of the conjunctiva. Other glands, analogous to lymphoid follicles, and called by Henle *trachoma glands*, are found in the conjunctiva, and, according to Stromeyer, are chiefly situated near the medial palpebral commissure. They were first described by Brush, in his description of Peyer's patches of the small intestine, as 'identical structures existing in the under eyelid of the ox.'

The *caruncula lacrimalis* (fig. 894) is a small, reddish, conical body situated at the medial palpebral commissure, and filling up the *lacus lacrimalis*. It consists of a small island of skin containing sebaceous and sudiferous glands, and is the source of the whitish secretion which constantly collects in this region. A few slender hairs are attached to its surface. Lateral to the caruncula is a slight semilunar fold of conjunctiva, the concavity of which is directed towards the cornea; it is called the *plica semilunaris*. Müller found smooth muscular fibres in this fold; in some of the domesticated animals it contains a thin plate of cartilage.

The nerves of the conjunctiva are numerous; many of them end in terminal bulbs, first described by Krause (p. 1005).

LACRIMAL APPARATUS (fig. 898)

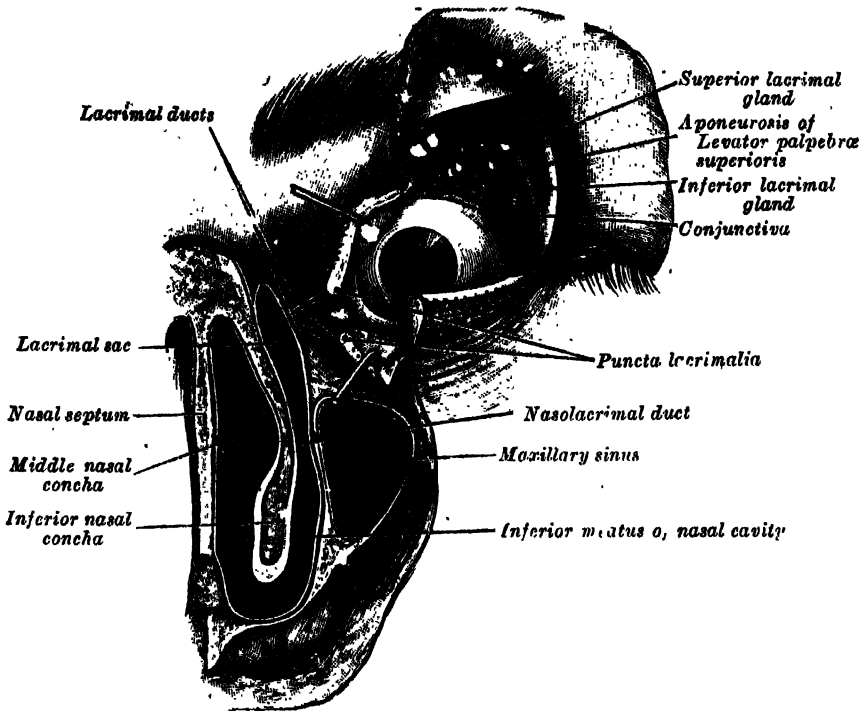
The lacrimal apparatus consists of (a) the lacrimal gland which secretes the tears, and its excretory ducts which convey the fluid to the surface of the eye; (b) the lacrimal ducts, the lacrimal sac, and the nasolacrimal duct, by which the fluid is conveyed into the cavity of the nose.

The *lacrimal gland* is lodged in the lacrimal fossa, on the medial side of the zygomatic process of the frontal bone. It is of an oval form, about the size and shape of an almond, and consists of two portions, described as the superior and inferior lacrimal glands. The *superior lacrimal gland* is connected to the periosteum of the orbit by a few fibrous bands; the *inferior lacrimal gland* is separated from the superior by the aponeurosis of the Levator palpebræ superioris, and projects into the back part of the upper eyelid, where its deep surface is related to the conjunctiva. The ducts of the glands, from six to twelve in number, run obliquely beneath the conjunctiva for a short distance, and open along the lateral half of the superior conjunctival fornix.

Structure of the lacrimal gland (fig. 899).—In structure and general appearance the lacrimal resembles the salivary glands (p. 1053). It is a compound *racemose gland*, the alveoli of which are lined by columnar cells resting on a basement membrane. The cells contain oval nuclei, and in the resting condition are crowded with small clear vacuoles, which disappear when the gland secretes actively; protoplasmic granules are also present. The ducts are lined by columnar epithelial cells which do not show the rod-like structure of the corresponding cells in the salivary glands.

The lacrimal ducts or canals, one in each eyelid, commence as minute orifices, termed *puncta lacrimalia*, on the summits of the *papillae lacrimales*, seen on the margins of the lids at the lateral extremity of the lacus lacrimalis.

FIG. 898.—The lacrimal apparatus. Left side.



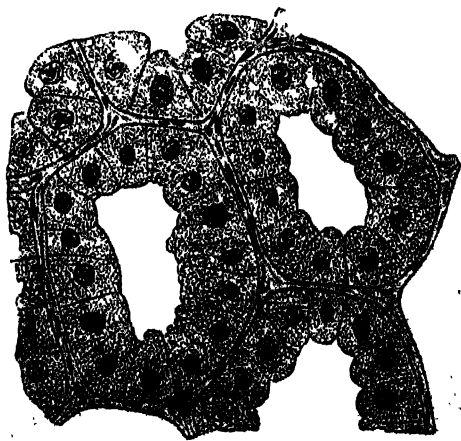
The *superior duct*, the smaller and shorter of the two, at first ascends, and then bends at an acute angle, and passes medialwards and downwards to the lacrimal sac. The *inferior duct* at first descends, and then runs almost horizontally to the lacrimal sac. At the angles they are dilated into *ampullae*; their walls are dense in structure and their mucous lining is covered by stratified squamous epithelium, placed on a basement membrane. Outside the latter is a layer of striped muscle, continuous with the lacrimal part of the Orbicularis oculi; at the base of each lacrimal papilla the muscular fibres are circularly arranged and form a kind of sphincter.

The lacrimal sac is the upper dilated end of the nasolacrimal duct, and is lodged in a deep groove formed by the lacrimal bone and frontal process of the maxilla. It is oval in form and measures from 12 to 15 mm. in

length; its upper end is closed and rounded; its lower is continued into the nasolacrimal duct; in its lateral wall are the openings of the lacrimal ducts.

Relations.—The lacrimal sac is intimately related to the medial palpebral ligament which extends from the medial ends of the tarsal plates of the eyelids and

FIG. 899.—A transverse section of a portion of the lacrimal gland of a cat. $\times 250$.



divides into a strong anterior, and a weak posterior, lamina. The anterior lamina, the medial palpebral ligament (*tendo oculi*), passes in front of the upper part of the lacrimal sac and is attached to the anterior lacrimal crest and to the frontal process of the maxilla, anterior to this crest. This lamina is connected to the upper part of the lacrimal sac, but is separated from the lower part by some fibres of the *Orbicularis oculi* which pass deep to it, thus leaving its lower margin free and conspicuous after removal of the skin. The posterior lamina of the medial palpebral ligament passes behind and is adherent to the lacrimal sac and is attached to the posterior lacrimal crest; the lacrimal part of the *Orbicularis oculi* is also behind the sac.

The lower half of the fossa which lodges the lacrimal sac is related medially with the anterior part of the middle meatus of the nasal cavity; the upper half with the anterior ethmoidal cells.

S. B. Whitnall * examined 100 skulls and found that in 14 per cent. the anterior ethmoidal cells came into relation only with the posterior wall of the fossa; in 32 per cent. they reached as far forward as the suture between the lacrimal bone and the maxilla; while in 54 per cent. one large irregular cell extended forward as far as the anterior lacrimal crest.

Structure.—The lacrimal sac consists of a fibrous elastic coat, lined internally by mucous membrane; the latter is continuous, through the lacrimal ducts, with the conjunctiva, and through the nasolacrimal duct with the mucous membrane of the nasal cavity. The tears pass from the superolateral to the inferomedial angle of the conjunctival sac. They are directed by: (a) the medialward pull of the *Orbicularis oculi*; (b) the contractions of the muscle around the lacrimal ducts; and (c) the compression of the lacrimal sac by the lacrimal part of the *Orbicularis oculi*.

The **nasolacrimal duct** (nasal duct) is a membranous canal, about 18 mm. long, which extends from the lower part of the lacrimal sac to the anterior part of the inferior meatus of the nose, where it ends in a somewhat expanded orifice, provided with an imperfect valve, the *plica lacrimalis* (*Hasneri*), formed by a fold of the mucous membrane. It is contained in an osseous canal, formed by the maxilla, the lacrimal bone, and the inferior nasal concha; it is narrower in the middle than at either end, and is directed downwards, backwards, and a little lateralwards. The mucous lining of the lacrimal sac and nasolacrimal duct is covered with columnar epithelium which in places is ciliated.

Applied Anatomy.—The eyelids are composed of various tissues, and consequently are liable to a variety of diseases. The skin covering them is thin and delicate, and is supported on a quantity of loose areolar subcutaneous tissue, devoid of fat. In consequence of this it is very freely movable, and is liable to be drawn down by the contraction of neighbouring cicatrices, and thus produces an eversion of the lid, known as *ectropion*. Inversion of the lids (*entropion*) from spasm of the *Orbicularis oculi* or from chronic inflammation of the palpebral conjunctiva may also occur. The loose cellular tissue beneath the skin is liable to become extensively infiltrated either with blood or inflammatory products, producing very great swelling. Even from very slight injuries to this tissue, the extravasation of blood may be so great as to produce considerable swelling of the eyelids and complete closure of the eye, and the same is the case when inflammatory products are poured out. The follicles of the eyelashes, or the sebaceous glands associated with these follicles, may be the seat of inflammation, constituting the ordinary 'stye.' Irregular or disorderly growth of the eyelashes not infrequently occurs, some of them being turned towards the eyeball and producing inflammation and ulceration of the cornea, and possibly eventually complete destruction of the eye. The *Orbicularis oculi* may be the seat of spasm, either in the form of slight quivering of the lids; or repeated twitchings, most commonly due to errors of refraction in children; or more continuous spasms, due to some irritation of the trigeminal or of the facial nerve. The *Orbicularis oculi* may be paralysed with the other facial muscles. Under these circumstances the patient is unable to close the lids, and, if he attempts to do so, rolls the eyeball upwards under the upper eyelid. The tears overflow from displacement of the lower eyelid, and the conjunctiva and cornea, being constantly exposed and the patient being unable to wink, become irritated from dust and foreign bodies. Ptosis, or drooping of the upper eyelid, may be congenital, or may be due to paralysis of the *Levator palpebræ superioris*, in which case there will probably be other symptoms of implication of the oculomotor nerve. The eyelids may be the seat of bruises, wounds, or burns. Following burns, adhesion of the margins of the lids to each other, or adhesion of the lids to the bulb may take place. They are sometimes the seat of emphysema, after fracture of some of the thin bones forming the medial wall of the orbit. If shortly after such an injury the patient blows his nose, air is forced from the nostril through the lacerated structures

into the connective tissue of the eyelids, which suddenly swell up and present the peculiar crackling characteristic of this affection.

Foreign bodies frequently get into the conjunctival sac and cause great pain, especially if they come in contact with the corneal surface, during the movements of the eyelids and the eye on each other. The conjunctiva is often involved in severe injuries of the eyeball, but is seldom ruptured alone; the most common form of injury to the conjunctiva alone is from a burn, either from fire, strong acids, or lime. In these cases union is liable to take place between the eyelid and the eyeball. The conjunctiva is often the seat of inflammation arising from many different causes, and the arrangement of the conjunctival vessels should be remembered as affording a means of diagnosis between this condition and injection of the sclera, which is present in inflammation of the deeper structures of the bulb of the eye. The inflamed conjunctiva is bright red; the vessels are large and tortuous, and greatest at the circumference, shading off towards the corneal margin; they anastomose freely and form a dense network, and they can be emptied or displaced by gentle pressure. Inflammation of the underlying sclera, ciliary body, or iris, is a far more serious condition; the injection is in the deeper vessels of the eye, and as seen through the sclera presents a diffuse and dull purplish or violet zone of circumcorneal discoloration.

The lacrimal ducts may become occluded as a result of burns or injury; overflow of the tears may also result from deviation of the puncta, or from chronic inflammation of the lacrimal sac. This latter condition is set up by some obstruction to the nasolacrimal duct, frequently associated with some infection from the nasal cavity. In consequence of this the tears and mucus accumulate in the lacrimal sac and distend it. Suppuration in the lacrimal sac is sometimes met with: this may be the sequel of a chronic inflammation. It may lead to lacrimal fistula from an abscess forming in the sac, which bursts or is opened on the surface: the condition is often seen in badly nourished, tuberculous children.

THE ORGAN OF HEARING

The ear or organ of hearing is divisible into three parts: the external ear, the middle ear or tympanic cavity, and the internal ear or labyrinth.

THE EXTERNAL EAR

The **external ear** consists of the expanded portion named the *auricula* or *pinna*, and the *external acoustic meatus*. The former projects from the side of the head and serves to collect the vibrations of the air by which sound is produced; the latter leads inwards from the bottom of the auricula and conducts the vibrations to the tympanic cavity.

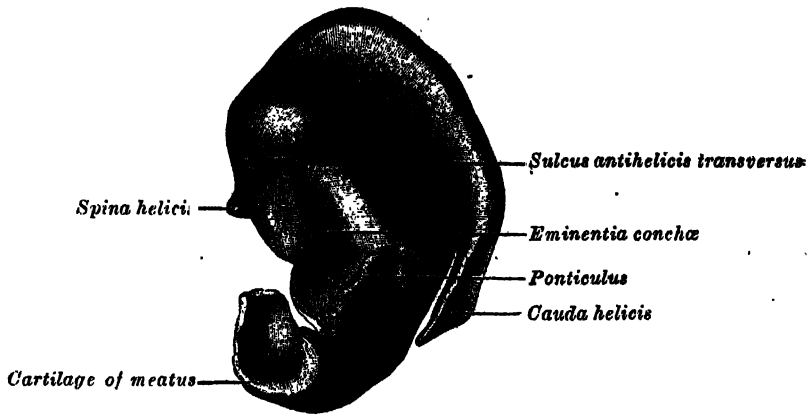
FIG. 900.—The right auricula. Lateral surface.

The **auricula** or **pinna** (fig. 900) is of an oval form, with its larger end directed upwards. Its lateral surface is irregularly concave, looks slightly forwards, and presents numerous eminences and depressions to which names have been assigned. The prominent rim of the auricula is called the *helix*; where the helix turns downwards behind, a small tubercle, the *auricular tubercle of Darwin*, is frequently seen; this tubercle is very evident about the sixth month of foetal life, when the whole auricula has a close resemblance to that of some of the adult monkeys. Another curved prominence, parallel with and in front of the helix, is called the *antihelix*; this divides above into two crura, between which is a triangular depression, the *fossa triangularis*. The narrow curved depression between the helix and the antihelix is called the *scapha*; the antihelix describes a curve round a deep, capacious cavity, the *concha*, which is incompletely divided into two parts by the *crus* or anterior end of the helix; the upper part is termed the *cymba conchae*, the lower part the *caelum conchae*. In front of the concha, and projecting backwards over the meatus, is a small pointed eminence, the *tragus*: so called from its being



generally covered on its under surface with a tuft of hair, resembling a goat's beard. Opposite the tragus, and separated from it by the *intertragic notch*, is a small tubercle, the *antitragus*. Below this is the *lobule*, composed of tough

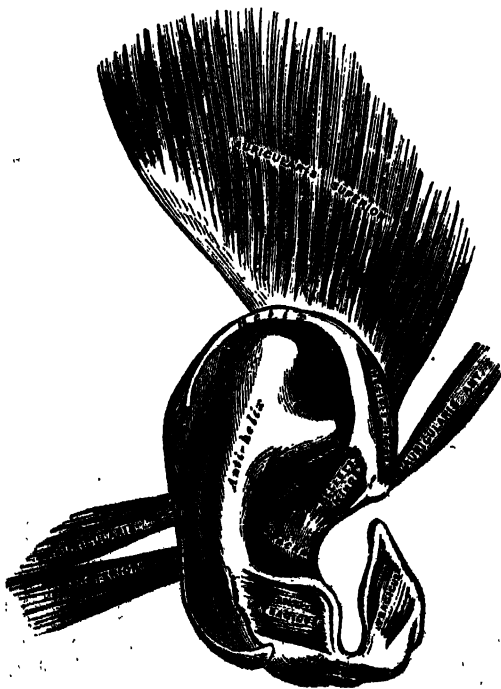
FIG. 901.—The cranial surface of the cartilage of the right auricle.



areolar and adipose tissues, and wanting the firmness and elasticity of the rest of the auricle.

The cranial surface of the auricle presents elevations which correspond to the depressions on its lateral surface, and after which they are named, e.g. eminentia conchæ, eminentia triangularis, &c.

FIG. 902.—The muscles of the auricle.



Structure.—The auricle is composed of a thin plate of yellow fibrocartilage, covered with skin, and connected to the surrounding parts by ligaments and muscles; it is continuous with the cartilaginous portion of the external acoustic meatus, and the latter is joined to the circumference of the porus acusticus externus by fibrous tissue.

The *skin* is thin, closely adherent to the cartilage, and covered with fine hairs furnished with sebaceous glands which are most numerous in the concha and scaphoid fossa. On the tragus and antitragus the hairs are strong and numerous. The skin of the auricle is continuous with that lining the external acoustic meatus.

The *cartilage of the auricle* (figs. 901, 902) consists of a single piece; upon its surface are found the eminences and depressions above described.

It is absent from the lobule; it is deficient, also, between

the tragus and beginning of the helix, the gap being filled up by dense fibrous tissue. At the front part of the auricle, where the helix bends upwards, is a small projection of cartilage, called the *spina heliciis*, while in the lower part of the helix the cartilage is prolonged downwards as a tail-like process.

the *cauda heliis*; this is separated from the antihelix by a fissure, the *fissura antitragohelicina*. The cranial aspect of the cartilage exhibits a transverse furrow, the *sulcus antiheliciis transversus*, which corresponds with the inferior crus of the antihelix and separates the eminentia conchæ from the eminentia triangularis. The eminentia conchæ is crossed by a vertical ridge (*ponticulus*) which gives attachment to the Auricularis posterior muscle. In the cartilage of the auricula are two fissures, one behind the crus heliis and another in the tragus.

The ligaments of the auricula consist of two sets: (1) extrinsic, connecting it to the side of the head; (2) intrinsic, connecting various parts of its cartilage together.

The extrinsic ligaments are two in number, anterior and posterior. The anterior ligament extends from the tragus and spina heliis to the root of the zygomatic process of the temporal bone. The posterior ligament passes from the posterior surface of the concha to the outer surface of the mastoid process.

The chief intrinsic ligaments are: (a) a strong fibrous band, stretching from the tragus to the helix, completing the meatus in front, and partly encircling the boundary of the concha; and (b) a band between the antihelix and the cauda heliis. Other less important bands are found on the cranial surface of the pinna.

The muscles of the auricula (fig. 902) consist of two sets: (1) the extrinsic, which connect it with the skull and scalp and move the auricula as a whole; and (2) the intrinsic, which extend from one part of the auricula to another.

The extrinsic muscles are the Auriculares anterior, superior, and posterior.

The Auricularis anterior, the smallest of the three, is thin, fan-shaped, and its fibres are pale and indistinct. It arises from the lateral edge of the galea aponeurotica, and its fibres converge to be inserted into the spina heliis.

The Auricularis superior, the largest of the three, is thin and fan-shaped. Its fibres arise from the galea aponeurotica, and converge to be inserted by a thin, flattened tendon into the upper part of the cranial surface of the auricula.

The Auricularis posterior consists of two or three fleshy fasciculi, which arise by short aponeurotic fibres from the mastoid portion of the temporal bone, and are inserted into the lower part of the cranial surface of the concha.

Actions.—In man, these muscles possess very little action: the Auricularis anterior draws the auricula forwards and upwards; the Auricularis superior slightly raises it; and the Auricularis posterior draws it backwards.

The intrinsic muscles are the:

Helicis major.

Antitragicus.

Helicis minor.

Transversus auriculæ.

Tragicus.

Obliquus auriculæ.

The *Helicis major* is a narrow vertical band situated upon the anterior margin of the helix. It arises from the spina heliis, and is inserted into the anterior border of the helix, just where it is about to curve backwards.

The *Helicis minor* is an oblique fasciculus, covering the crus heliis.

The *Tragicus* is a short, flattened vertical band on the lateral surface of the tragus.

The *Antitragicus* arises from the outer part of the antitragus, and is inserted into the cauda heliis and antihelix.

The *Transversus auriculæ* is placed on the cranial surface of the pinna. It consists of scattered fibres, partly tendinous and partly muscular, extending from the eminentia conchæ to the eminentia scaphæ.

The *Obliquus auriculæ*, also on the cranial surface, consists of a few fibres extending from the upper and back part of the eminentia conchæ to the eminentia triangularis.

Nerves.—The Auriculares anterior and superior, and the intrinsic muscles on the lateral surface, are supplied by the temporal branches of the facial nerve, the Auricularis posterior and the intrinsic muscles on the cranial surface by the posterior auricular branch of the same nerve.

The arteries of the auricula are: (a) the posterior auricular branch of the external carotid artery, which supplies three or four branches to the cranial surface; from these branches twigs reach the lateral surface, partly by passing through the fissures of the auricular cartilage, and partly by turning round the margin of the helix; (b) the anterior auricular branches of the superficial temporal artery, which are distributed to the lateral surface; and (c) a branch from the occipital artery.

The veins accompany the corresponding arteries.

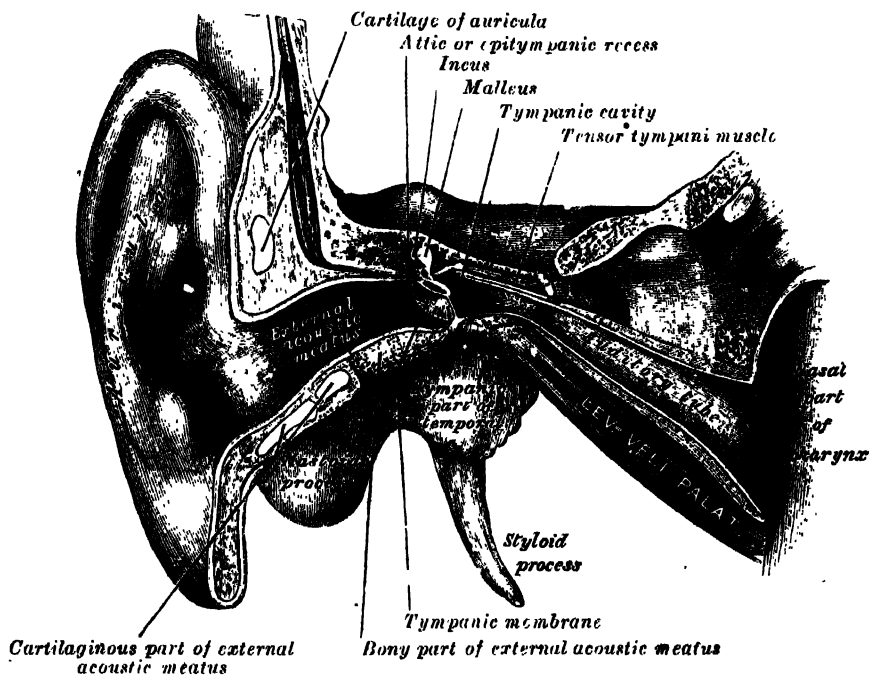
The sensory nerves are: the great auricular nerve, from the cervical plexus; the auricular branch of the vagus nerve; the auriculotemporal branch of the mandibular nerve; and the lesser occipital nerve from the cervical plexus.

The external acoustic meatus extends from the bottom of the concha to the tympanic membrane (figs. 903, 904). It is about 4 cm. long if measured from the tragus; from the bottom of the concha its length is about 2.5 cm.

It forms an S-shaped curve, and is directed at first inwards, forwards, and slightly upwards (*pars externa*) ; it then passes inwards and backwards (*pars media*), and lastly is carried inwards, forwards, and slightly downwards (*pars interna*). It is an oval cylindrical canal, the greatest diameter being directed downwards and backwards at the external orifice, but nearly horizontally at the inner end. It presents two constrictions, one near the inner end of the cartilaginous portion, and another, named the *isthmus*, in the osseous portion, about 2 cm. from the bottom of the concha. The tympanic membrane, which closes the inner end of the meatus, is obliquely directed ; in consequence of this obliquity the floor and anterior wall of the meatus are longer than the roof and posterior wall.

The external acoustic meatus is formed partly by cartilage and membrane, and partly by bone, and is lined by skin.

FIG. 903.—The external and middle portions of the ear, opened from the front.
Right side.



The *cartilaginous portion* is about 8 mm. long; it is continuous with the cartilage of the auricula, and is fixed to the circumference of the porus acusticus externus of the temporal bone. The cartilage is deficient at the upper and posterior parts of the meatus, its place being supplied by fibrous membrane; two or three deep fissures are present in the anterior part of the cartilage.

The *osseous portion* is about 16 mm. long, and is narrower than the cartilaginous portion. It is directed inwards and a little forwards, forming in its course a slight curve the convexity of which is upwards and backwards. Its inner end is smaller than the outer, and sloped, the anterior wall projecting beyond the posterior for about 4 mm.; this end is marked, except at its upper part, by a narrow groove, the *tympanic sulcus*, to which the circumference of the tympanic membrane is attached. Its outer end (*porus acusticus externus*) is dilated and rough in the greater part of its circumference, for the attachment of the cartilaginous portion. The anterior and inferior parts of the osseous portion are formed by the tympanic part of the temporal bone, which, in the fœtus, exists as the tympanic ring (p. 210).

The skin which envelops the auricula is continued into the external acoustic meatus and covers the outer surface of the tympanic membrane. It is thin and closely adherent to the cartilaginous and osseous parts of the tube. After

maceration, the thin pouch of epidermis, when withdrawn, preserves the form of the meatus. In the thick subcutaneous tissue of the cartilaginous part of the meatus are numerous *ceruminous glands* which secrete the ear-wax; their structure resembles that of the sudoriferous glands.

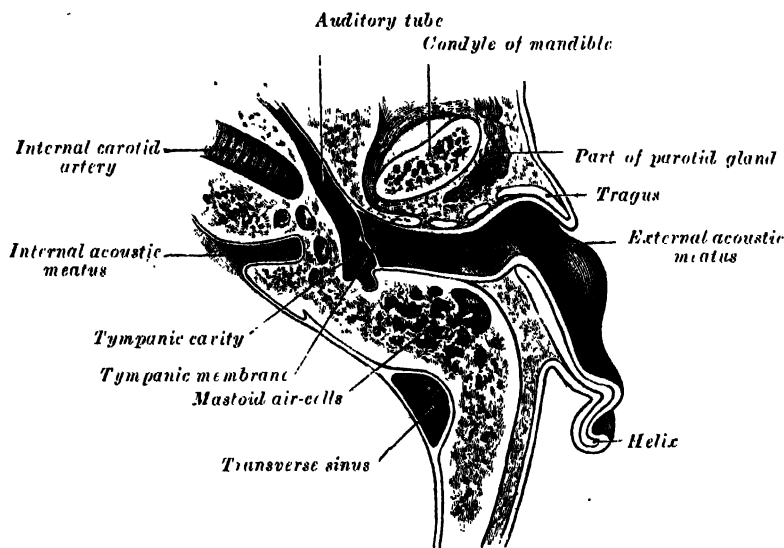
Relations of the meatus.—In front of the osseous part is the condyle of the mandible, which, however, is sometimes separated from the cartilaginous part by a small portion of the parotid gland. The movements of the mandible influence to some extent the lumen of this latter portion. Above the osseous part is the middle fossa of the skull; behind it are the mastoid air-cells, separated from the meatus by a thin layer of bone.

The *arteries* supplying the meatus are branches from the posterior auricular, internal maxillary, and temporal arteries.

The *nerves* are chiefly derived from the auriculotemporal branch of the mandibular nerve and the auricular branch of the vagus nerve.

Applied Anatomy.—Malformations, such as imperfect development of the external parts, supernumerary auriculae, or absence of the meatus, are occasionally met with. The skin of the auricula is thin and richly supplied with blood, but in spite of this it is

FIG. 904.—A horizontal section through the left ear. Upper half of the section.



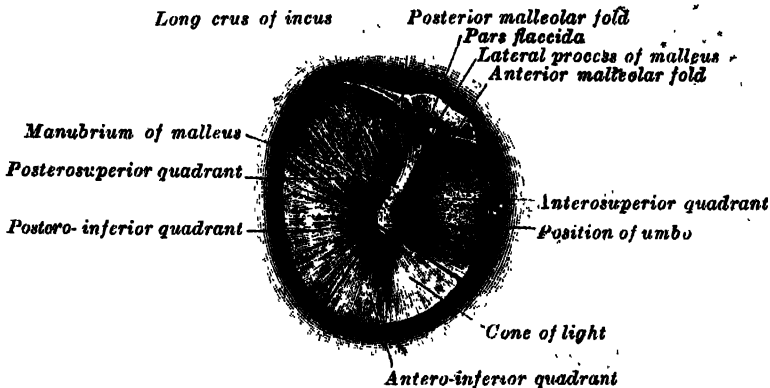
often the seat of frost-bite, due to the fact that it is much exposed to cold, and lacks the usual underlying subcutaneous fat found in most other parts of the body. A collection of blood is sometimes found between the cartilage and perichondrium (*hematoma auris*), usually the result of traumatism, but not necessarily due to this cause; it is said to occur most frequently in the ears of the insane. Deposits of urate of soda are often met with in the auriculae of gouty subjects.

The external acoustic meatus can be most satisfactorily examined by light reflected down a funnel-shaped speculum, when the greater part of the canal and tympanic membrane can be brought into view. In using this instrument, it is advisable that the auricula should be drawn upwards, backwards, and a little outwards, so as to render the meatus as straight as possible. The points to be noted are: the presence of wax or foreign bodies; the size of the meatus; and the condition of the tympanic membrane. Accumulation of wax is often a cause of deafness, and may give rise to very serious consequences, such as ulceration of the membrane; it is best removed by syringing. Foreign bodies are not infrequently introduced into the ear by children, and, when situated in the first portion of the meatus, may be removed with tolerable facility by means of a minute hook or loop of fine wire, aided by reflected light; but when they have slipped beyond the narrow middle part of the meatus, their removal is in no wise easy, and attempts to effect it, in inexperienced hands, may be followed by destruction of the tympanic membrane and possibly the contents of the tympanic cavity.

At the point of junction of the osseous and cartilaginous portions an obtuse angle, which projects into the tube at its antero-inferior wall, is formed; this produces a sort of constriction, and renders it a narrow portion of the meatus—an important point to be

remembered in connexion with the presence of foreign bodies in the meatus. The shortness of the meatus in children should be borne in mind in introducing the aural speculum, so that it be not pushed in too far, at the risk of injuring the tympanic membrane; indeed, even in the adult the speculum should never be introduced beyond the constriction which marks the junction of the osseous and cartilaginous portions. Just in front of the membrane is a well-marked depression, situated on the floor of the meatus, and bounded by a somewhat prominent ridge; in this foreign bodies may become lodged. By aid of the speculum, or, timed with traction of the auricle upwards and backwards, the greater part of the tympanic membrane is rendered visible (fig. 905). It is a pearly-grey membrane, slightly glistening in the adult, placed obliquely, so as to form with the floor of the meatus a very acute angle (about fifty-five degrees), while with the roof it forms an obtuse angle. At birth it is more horizontal, situated in almost the same plane as the base of the skull. About midway between the anterior and posterior margins of the membrane, and extending from the centre obliquely upwards, is a reddish-yellow streak; this is the handle of

FIG. 905.—The right tympanic membrane, as seen through a speculum.



the malleus, which is inserted into the membrane. At the upper part of this streak, close to the roof of the meatus, a little white, rounded prominence is plainly to be seen; this is the lateral or short process of the malleus, projecting against the membrane. The tympanic membrane does not present a plane surface; on the contrary, its centre is drawn inwards, on account of its connexion with the manubrium of the malleus, and thus the external surface is rendered concave.

The connexions of the nerves of the meatus explain the occurrence of constant coughing and sneezing, from implication of the vagus, when there exists any source of irritation in the meatus; and the vomiting which may follow syringing the ears of children, and the occasional heart failure similarly induced in elderly people. No doubt also the association of earache with toothache or with cancer of the tongue is due to implication of the mandibular branch of the trigeminal nerve, which supplies also the teeth and the tongue. The upper half of the tympanic membrane is much more vascular than the lower half; for this reason, and also to avoid the chorda tympani nerve and ossicles, incisions through the membrane should be made at the lower and posterior part.

THE MIDDLE EAR, OR TYMPANIC CAVITY

The middle ear, or tympanic cavity, is an irregular, laterally compressed space within the temporal bone. It is filled with air, which is conveyed to it from the nasal part of the pharynx through the auditory tube. It contains a chain of movable bones, which connect its lateral to its medial wall, and transmit the vibrations of the tympanic membrane across the cavity to the internal ear.

The tympanic cavity consists of two parts: the *tympanic cavity proper*, opposite the tympanic membrane, and the *attic* or *epitympanic recess*, above the level of the membrane; the latter contains the upper half of the malleus and the greater part of the incus. Including the attic, the vertical and antero-posterior diameters of the cavity are each about 15 mm. The transverse diameter measures about 6 mm. above and 4 mm. below; opposite the centre of the tympanic membrane it is only about 2 mm. The tympanic cavity is bounded laterally by the tympanic membrane; medially, by the lateral wall

of the internal ear; it communicates, behind, with the tympanic antrum and through it with the mastoid air-cells, and in front with the auditory tube (fig. 903).

The tegmental wall or roof of the tympanic cavity is formed by a thin plate of bone, the *tegmen tympani*, which separates the cranial and tympanic cavities and forms the greater part of the anterior surface of the petrous portion of the temporal bone; it is prolonged backwards so as to roof the tympanic antrum, and forwards to cover the semicanal for the Tensor tympani muscle.

The jugular wall or floor is narrow, and consists of a thin plate of bone (*fundus tympani*) which separates the tympanic cavity from the jugular fossa. In it, near the labyrinthine wall, is a small aperture for the passage of the tympanic branch of the glossopharyngeal nerve.

The membranous or lateral wall of the tympanic cavity is formed mainly by the tympanic membrane, but partly by the ring of bone in which this membrane is attached. There is a deficiency or notch in the upper part of the ring (*notch of Rivinus*), close to which are three small apertures, viz.: the *iter chordæ posterius*, the petrotympanic fissure, and the *iter chordæ anterior*.

The *iter chordæ posterius* (apertura tympanica canaliculi chordæ) is situated in the angle of junction between the mastoid and membranous walls of the tympanic cavity, immediately behind the tympanic membrane and on a level with the upper end of the manubrium mallei; it leads into a minute canal, which descends in front of the canal for the facial nerve, and ends in that canal about 6 mm. above the stylomastoid foramen. Through it the chorda tympani nerve and a branch of the stylo-mastoid artery enter the tympanic cavity.

The *petrotympanic fissure* (Gla-serian fissure) opens just above and in front of the ring of bone into which the tympanic membrane is inserted; in this situation it is a mere slit about 2 mm. in length. It lodges the anterior process and anterior ligament of the malleus, and transmits to the tympanic cavity the anterior tympanic branch of the internal maxillary artery.

The *iter chordæ anterior* (canal of Huguier) is placed at the medial end of the petrotympanic fissure; through it the chorda tympani nerve leaves the tympanic cavity.

The tympanic membrane (figs. 905, 906) separates the tympanic cavity from the bottom of the external acoustic meatus. It is a thin, semitransparent membrane, nearly oval in form, somewhat broader above than below, and placed very obliquely, forming an angle of about fifty-five degrees with the floor of the meatus. Its longest diameter is downwards and forwards, and measures from 9 to 10 mm.; its shortest diameter from 8 to 9 mm. The greater part of its circumference is thickened, and forms a *fibrocartilaginous ring* which is fixed in the *tympanic sulcus* at the inner end of the meatus. This sulcus is deficient superiorly at the notch of Rivinus, and from the ends of this notch two bands, the *anterior and posterior malleolar folds*, are prolonged to the lateral process of the malleus. The small, somewhat triangular part of the membrane

FIG. 906.—The membranous wall of the tympanic cavity. (Testut.)



The malleus has been resected immediately below its lateral process, in order to show the malleolar folds and the pars flaccida.

1. Tympanic membrane. 2. Umbo. 3. Manubrium mallei. 4. Lateral process. 5. Anterior malleolar fold. 6. Posterior malleolar fold. 7. Pars flaccida. 8, 9. Anterior and posterior pouches of Tröltsch. 10. Fibrocartilaginous ring. 11. Petrotympanic fissure. 12. Auditory tube. 13. *Iter chordæ posterius*. 14. *Iter chordæ anterior*. 15. Fossa incudis for short crus of the incus. 16. Prominentia styloidea.

situated above these folds is lax and thin, and is named the *pars flaccida* (membrane of Shrapnell); a small orifice is sometimes seen in it. The chief part of the membrane is taut and is named the *pars tensa*. The manubrium of the malleus is firmly attached to the medial surface of the tympanic membrane as far as its centre, which it draws towards the tympanic cavity; the medial surface of the membrane is thus convex, and the point of greatest convexity is named the *umbo*.

Structure.—The tympanic membrane is composed of three strata: a lateral (cutaneous), an intermediate (fibrous), and a medial (mucous). The *cutaneous stratum* is derived from the skin which lines the external acoustic meatus, and consists of stratified epithelium. The *fibrous stratum* consists of two layers: a radiate stratum, the fibres of which diverge from the manubrium of the malleus, and a deeper circular stratum, the fibres of which are plentiful around the circumference but sparse and scattered near the centre of the membrane. Branched or dendritic fibres (Grüber) are also present, especially in the posterior half of the membrane. The *mucous stratum* is part of the mucous membrane of the tympanic cavity; it is thickest towards the upper part of the membrane, and is covered by a single layer of flattened cells. In the *pars flaccida* of the membrana tympani the fibrous stratum is replaced by loose connective tissue.

Vessels and Nerves.—The arteries of the tympanic membrane are derived from the deep auricular branch of the internal maxillary artery, which ramifies beneath the cutaneous stratum; and from the stylomastoid branch of the posterior auricular artery, and tympanic branch of the internal maxillary artery, which are distributed to the mucous surface. The superficial veins open into the external jugular vein; those on the deep surface drain partly into the transverse sinus and veins of the dura mater, and partly into a plexus of veins on the auditory tube. The membrane receives its nerve supply from the auriculotemporal branch of the mandibular nerve, the auricular branch of the vagus nerve, and the tympanic branch of the glossopharyngeal nerve.

The labyrinthic or medial wall (fig. 907) of the tympanic cavity is formed by the lateral wall of the internal ear. It presents for examination the fenestra vestibuli, the fenestra cochleæ, the promontory, and the prominence of the facial canal.

The *fenestra vestibuli* (fenestra ovalis) is a reniform opening, situated above and behind the promontory, and leading from the tympanic cavity into the vestibule of the internal ear; its long diameter is horizontal, and its convex border is upwards. In the recent state it is occupied by the base of the stapes, the circumference of which is fixed to the margin of the fenestra by the ligamentum annulare basos stapodis.

The *fenestra cochleæ* (fenestra rotunda) is situated below and a little behind the fenestra vestibuli, from which it is separated by the promontory. It is placed at the bottom of a funnel-shaped depression and, in the macerated bone, leads into the scala tympani of the cochlea; in the recent state it is closed by the secondary tympanic membrane, which is somewhat concave towards the tympanic cavity, and convex towards the cochlea, the membrane being bent so that its posterosuperior third forms an angle with its antero-inferior two-thirds. This membrane consists of three layers: an external, derived from the mucous lining of the tympanic cavity; an internal, from the lining membrane of the cochlea; and an intermediate, or fibrous layer.

The *promontory* is a rounded prominence, formed by the projection outwards of the first turn of the cochlea; it is placed between the fenestra vestibuli and fenestra cochleæ, and its surface is furrowed by small grooves which lodge the nerves of the tympanic plexus. A minute spicule of bone frequently connects the promontory to the pyramidal eminence.

The *prominence of the facial canal* indicates the position of the upper part of the bony canal (aqueductus Fallopii), in which the facial nerve is contained; this canal traverses the labyrinthic wall of the tympanic cavity above the fenestra vestibuli, and then curves downwards along the mastoid wall.

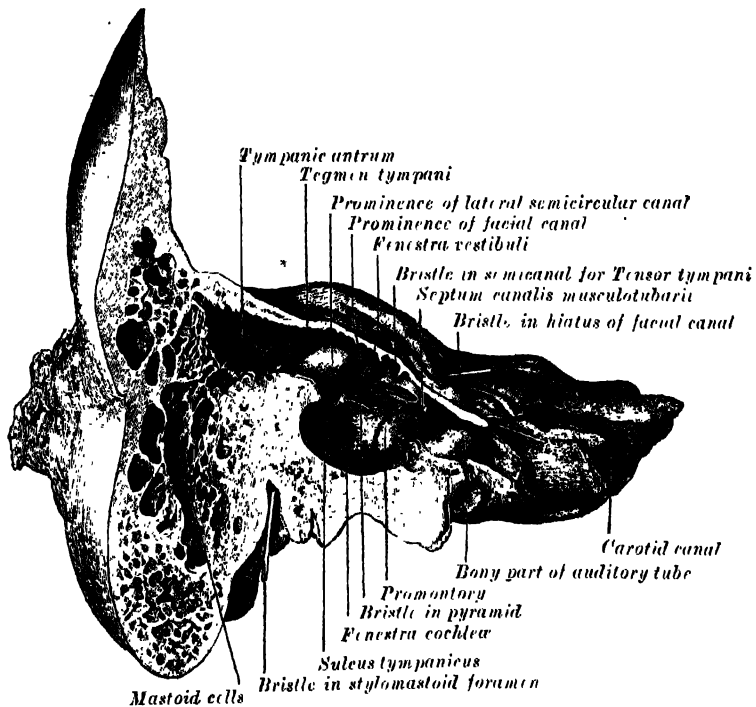
The *mastoid or posterior wall* of the tympanic cavity is wider above than below, and presents for examination the entrance to the tympanic antrum, the pyramidal eminence, and the fossa incudis.

The *entrance to the antrum* is a large irregular aperture, which leads backwards from the epitympanic recess into an air-space, named the *tympanic or mastoid antrum* (p. 206). The antrum communicates behind and below with

the *mastoid air-cells*, which vary considerably in number, size, and form; the antrum and mastoid air-cells are lined by mucous membrane, continuous with that lining the tympanic cavity. On the medial wall of the entrance to the antrum is a rounded eminence, situated above and behind the prominence of the facial canal; it corresponds with the position of the ampullated ends of the superior and lateral semicircular canals.

The *pyramidal eminence* is situated immediately behind the fenestra vestibuli, and in front of the vertical portion of the facial canal; it is hollow, and contains the Stapedius muscle; its summit projects forwards towards the fenestra vestibuli, and is pierced by a small aperture which transmits the tendon of the muscle. The cavity in the pyramidal eminence is prolonged downwards

FIG. 907.—A coronal section of the right temporal bone



and backwards in front of the facial canal, and communicates with it by a minute aperture which transmits a twig from the facial nerve to the Stapedius muscle.

The *fossa incudis* is a small depression in the lower and posterior part of the epitympanic recess; it lodges the short crus of the incus, which is fixed to the fossa by ligamentous fibres.

The *carotid* or *anterior wall* of the tympanic cavity is narrowed in its vertical diameter by the descent of the tegmen tympani; it is separated from the carotid canal by a thin plate of bone perforated by the tympanic branch of the internal carotid artery, and by the caroticotympanic nerves. At the upper part of the anterior wall are the orifice of the semicanal for the Tensor tympani muscle, and the tympanic orifice of the auditory tube, separated from each other by a thin horizontal plate of bone, the septum canalis musculotubarii. These canals run from the tympanic cavity forwards and downwards to the angle of union between the squama and the petrous portion of the temporal bone.

The *semicanal for the Tensor tympani* is the higher and the smaller of the two; it is cylindrical and lies beneath the tegmen tympani. It extends on to the labyrinthine wall of the tympanic cavity, and ends immediately above the fenestra vestibuli.

The *septum canalis musculotubarii* (processus cochleariformis) passes backwards below this semicanal, forming its lateral wall and floor; it expands above the anterior end of the fenestra vestibuli, and terminates there by curving laterally so as to form a pulley over which the tendon of the muscle passes.

The **auditory tube** (Eustachian tube) is the channel through which the tympanic cavity communicates with the nasal part of the pharynx. Its length is about 36 mm., and its direction is downwards, forwards, and medial-wards, forming an angle of about 45° with the sagittal plane and one of about 30° with the horizontal plane. It is formed partly of bone, partly of cartilage and fibrous tissue (fig. 903).

The *osseous portion* is about 12 mm. long. It begins in the carotid wall of the tympanic cavity, below the septum canalis musculotubarii, and, gradually narrowing, ends at the angle of junction of the squama and the petrous portion of the temporal bone, its extremity presenting a jagged margin which serves for the attachment of the cartilaginous portion.

The *cartilaginous portion*, about 24 mm. long, is formed of a triangular plate of elastic fibrocartilage, the greater part of which is situated in the medial wall of the tube. The apex of the fibrocartilage is attached by fibrous tissue to the circumference of the medial end of the osseous portion of the tube, while its base lies directly under the mucous membrane of the lateral wall of the nasal part of the pharynx, where it forms an elevation, the *torus tubarius* or *cushion*, behind the pharyngeal orifice of the tube. The upper edge of the cartilage is bent laterally so as to present on transverse section the appearance of a hook; a groove or furrow is thus produced, which is open below and laterally, and this part of the canal is completed by fibrous membrane. The cartilage lies in a groove between the petrous part of the temporal and the great wing of the sphenoid; this groove ends opposite the middle of the medial pterygoid lamina. The cartilaginous and bony portions of the tube are not in the same plane, the former inclining downwards a little more than the latter. The diameter of the tube is not uniform throughout, being greatest at the pharyngeal orifice, least at the junction of the bony and cartilaginous portions, and again increased towards the tympanic cavity; the narrowest part of the tube is termed the *isthmus*. The position and relations of the pharyngeal orifice are described with the nasal part of the pharynx (p. 1076). The mucous membrane of the tube is continuous in front with that of the nasal part of the pharynx, and behind with that of the tympanic cavity; it is covered with ciliated epithelium and is thin in the osseous portion, while in the cartilaginous portion it contains many mucous glands and near the pharyngeal orifice a considerable amount of adenoid tissue, named by Gerlach the *tube-tonsil*. The tube is opened during deglutition by the Salpingopharyngeus and Dilator tubæ. The latter arises from the lateral lamina of the cartilage and from the membranous part of the tube, and blends below with the Tensor veli palatini. H. Blakeway* is of opinion that contraction of the Tensor veli palatini is more likely to produce closure than opening of the tube.

In the new-born child the auditory tube is about half as long as that of the adult. Its direction is more horizontal and its osseous portion is relatively shorter. Its pharyngeal orifice is a narrow slit which is on a level with the palate, and is devoid of a torus tubarius.

Vessels and Nerves.—The *arteries* of the auditory tube are derived from the ascending pharyngeal branch of the external carotid artery and from two branches of the internal maxillary artery, viz.:—the middle meningeal artery and the artery of the pterygoid canal. The *veins* open into the pterygoid venous plexus. The *nerves* of the tube spring from the pharyngeal plexus and from the pharyngeal branch of the sphenopalatine ganglion.

AUDITORY OSSICLES

The tympanic cavity contains a chain of three-movable ossicles, the *malleus*, *incus*, and *stapes*. The malleus is attached to the tympanic membrane, the stapes to the circumference of the fenestra vestibuli, while the incus is placed between the malleus and stapes and connected to them by delicate articulations.

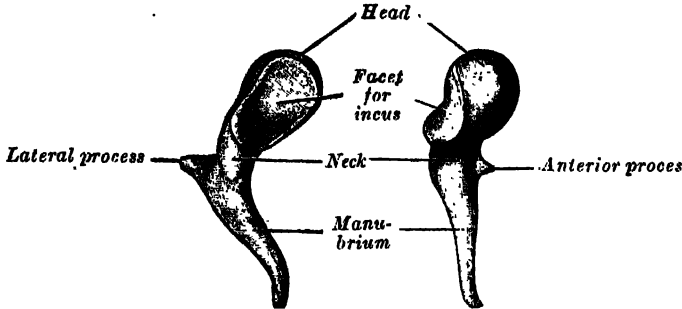
* *Journal of Anatomy and Physiology*, vol. xlviii.

THE AUDITORY OSSICLES

The **malleus** (fig. 908), so named from its fancied resemblance to a hammer, is from 8 to 9 mm. long, and is the largest of the auditory ossicles. It consists of a head, neck, and three processes, viz. the manubrium, the anterior and lateral processes.

The **head**, the large upper end of the bone, is situated within the epitympanic recess; it is ovoid in shape, and articulates posteriorly with the incus, being

FIG. 908.—The left malleus. A. From behind. B. From within.



free in the rest of its extent. The facet for articulation with the incus is constricted near the middle, and consists of an upper larger, and lower smaller part, situated nearly at right angles to one another. Opposite the constriction the lower margin of the facet projects in the form of a process, the *cog-tooth* or *spur* of the malleus.

The **neck** is the contracted part just beneath the head; below the neck is an enlargement to which the various processes are attached.

The **manubrium mallei** is connected by its lateral margin with the tympanic membrane. It is directed downwards, medialwards, and backwards; it decreases in size towards its free end, which is curved slightly forwards and flattened transversely. Near the upper end of its medial surface is a slight projection, into which the tendon of the Tensor tympani is inserted.

The **anterior process** (*processus gracilis*) is a delicate spicule, directed forwards from the enlargement below the neck; it is connected to the petrotympanic fissure by ligamentous fibres. In the foetus this is the longest process of the malleus, and is continuous in front with the cartilage of Meckel (p. 77).

The **lateral process** (*processus brevis*) is a slight conical projection, which springs from the root of the manubrium; it is directed laterally, and is attached to the upper part of the tympanic membrane and, by means of the anterior and posterior malleolar folds, to the extremities of the notch of Rivinus.

The **incus** (fig. 909) has received its name from its supposed resemblance to an anvil, but its shape is more like that of a premolar tooth, with two widely separated roots. It consists of a body and two crura.

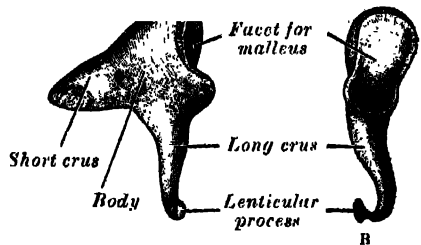
The **body** is somewhat cubical but compressed transversely. On its anterior surface is a saddle-shaped facet, for articulation with the head of the malleus.

The two crura diverge from one another nearly at right angles.

The **short crus**, somewhat conical in shape, projects backwards, and is attached by ligamentous fibres to the fossa incudis, in the lower and posterior part of the epitympanic recess.

The **long crus**, rather more than half the length of the manubrium mallei, descends nearly vertically behind and parallel to that process; its lower end bends medialwards, and terminates in a rounded projection, the **lenticular**

FIG. 909.—The left incus. A. From within. B. From the front.

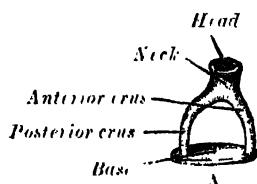


process, the inner surface of which is covered with cartilage, and articulates with the head of the stapes.

The **stapes** (fig. 910), so called from its resemblance to a stirrup, consists of a head, neck, two crura, and a base.

On the *head*, which is directed lateralwards, is a depression for articulation with the lenticular process of the incus.

FIG. 910.—A. The left stapes. B. Medial surface of the head of the stapes.



On the *neck* or constricted part succeeding the head, the tendon of the Stapedius muscle is inserted.

The *crura* diverge from the neck and are connected at their ends by a flattened oval plate, the *base*, which forms the footplate of the stirrup and is fixed to the margin of the fenestra vestibuli by a ring of ligamentous fibres. The anterior crus is shorter and less curved than the posterior.

Articulations of the auditory ossicles.—The incudomalleolar joint is a saddle-shaped diarthrosis; it is surrounded by an articular capsule, and the joint-cavity is incompletely divided into two by a wedge-shaped articular disc or meniscus. The incudostapedial joint is an enarthrosis, surrounded by an articular capsule; some observers have described an articular disc or meniscus in this joint; others regard the joint as a syndesmosis.

Ligaments of the ossicles.—The ossicles are connected to the walls of the tympanic cavity by ligaments: three for the malleus, and one each for the incus and stapes.

The *anterior ligament of the malleus* is attached by one end to the neck of the malleus, just above the anterior process, and by the other to the anterior wall of the tympanic cavity, close to the petrotympanic fissure, some of its fibres being prolonged through the fissure, to reach the spina angularis of the sphenoid.

The *lateral ligament of the malleus* is a triangular band passing from the posterior part of the notch of Rivinus to the head of the malleus. Helmholtz described the anterior ligament and the posterior part of the lateral ligament as forming together the '*axis ligament*' around which the malleus rotates.

The *superior ligament of the malleus* connects the head of the malleus to the roof of the epitympanic recess.

The *posterior ligament of the incus* connects the end of the short crus of the incus to the fossa incudis.

A *superior ligament of the incus* has been described, but it is little more than a fold of mucous membrane.

The vestibular surface and the circumference of the base of the stapes are covered with hyaline cartilage; that encircling the base is attached to the margin of the fenestra vestibuli by a ring of elastic fibres, the *ligamentum annulare baseos stapedis*.

Movements of the auditory ossicles.—The manubrium mallei follows all the movements of the tympanic membrane, while the malleus and incus rotate together around an axis which runs through the short process of the incus and the anterior ligament of the malleus. When the tympanic membrane and manubrium mallei are propelled inwards the long process of the incus also moves in the same direction and pushes the base of the stapes towards the labyrinth. This motion is communicated to the fluid (perilymph) contained within the labyrinth and the movement of the perilymph causes an outward bulging of the secondary tympanic membrane which closes the fenestra cochleæ. The conditions are reversed when the tympanic membrane moves in a lateral direction, but if this movement of the membrane be exaggerated the incus does not follow the full outward excursion of the malleus, but merely glides on this bone at the incudomalleolar joint, and thus the danger of pulling the foot of the stapes out of the fenestra vestibuli is prevented. When the manubrium mallei is carried inwards the cog-tooth or spur on the lower margin of the head of the malleus locks the incudomalleolar joint, and this necessitates an inward movement of the long process of the incus; the joint is unlocked when the manubrium mallei is carried outwards.

The **muscles of the tympanic cavity** are the Tensor tympani and Stapedius.

The *Tensor tympani*, the larger, is contained in the bony canal above the osseous portion of the auditory tube, from which it is separated by the septum

canalis musculotubarii. It arises from the cartilaginous portion of the auditory tube and the adjoining part of the great wing of the sphenoid, as well as from the osseous canal in which it is contained. Passing backwards through the canal, it ends in a slender tendon which enters the tympanic cavity, makes a sharp bend round the pulley-like posterior end of the septum, and is inserted into the manubrium mallei, near its root. It is supplied by a branch of the mandibular nerve through the otic ganglion.

The *Stapedius* arises from the wall of a conical cavity hollowed out of the interior of the pyramidal eminence; its tendon emerges from the orifice at the apex of the eminence, and, passing forwards, is inserted into the posterior surface of the neck of the stapes. It is supplied by a branch of the facial nerve.

Actions.—The Tensor tympani draws the manubrium mallei and the tympanic membrane medialwards, and thus increases the tension of the membrane. The Stapedius pulls back the head of the stapes, and thus causes the base of the bone to rotate on a vertical axis drawn through its own centre; the posterior part of the base is pressed inwards towards the vestibule, while the anterior part is withdrawn from it. By the action of the muscle the tension of the fluid within the internal ear is probably increased.

The mucous membrane of the tympanic cavity is continuous with that of the pharynx, through the auditory tube. It invests the auditory ossicles, and the muscles and nerves contained in the tympanic cavity; forms the medial layer of the tympanic membrane, and the lateral layer of the secondary tympanic membrane, and lines the tympanic antrum and mastoid cells. It forms several vascular folds, which extend from the walls of the tympanic cavity to the ossicles; of these, one descends from the roof of the cavity to the head of the malleus and upper margin of the body of the incus, a second invests the Stapedius muscle; other folds invest the chorda tympani nerve and the Tensor tympani muscle. These folds separate off pouch-like cavities, and give the interior of the tympanum a somewhat honeycombed appearance. One of these pouches, the *pouch of Prussak*, is well marked and lies between the neck of the malleus and the membrana flaccida. Two other recesses may be mentioned: they are formed by the mucous membrane which envelops the chorda tympani nerve, and are situated, one in front of, and the other behind, the manubrium of the malleus; they are named the *anterior and posterior recesses of Tröltsch*. In the tympanic cavity the mucous membrane is pale, thin, slightly vascular, and covered for the most part with columnar ciliated epithelium, but over the pyramidal eminence, ossicles, and tympanic membrane it possesses a flattened non-ciliated epithelium. In the tympanic antrum and mastoid cells its epithelium is also non-ciliated.

Vessels and Nerves.—The arteries are six in number. Two of them are larger than the others, viz. the tympanic branch of the internal maxillary artery, which supplies the tympanic membrane; and the stylo-mastoid branch of the posterior auricular artery, which is distributed to the posterior part of the tympanic cavity and mastoid cells. The smaller arteries are—the petrosal branch of the middle meningeal artery, which enters through the hiatus of the facial canal; a branch from the ascending pharyngeal artery, and another from the artery of the pterygoid canal, which accompany the auditory tube; and the tympanic branch from the internal carotid artery, given off in the carotid canal and perforating the thin anterior wall of the tympanic cavity. The veins terminate in the pterygoid venous plexus and in the superior petrosal sinus. The nerves constitute the tympanic plexus, which ramifies upon the surface of the promontory. The plexus is formed by (1) the tympanic branch of the glossopharyngeal nerve; (2) the carotico-tympanic nerves; (3) the smaller superficial petrosal nerve; and (4) a branch which joins the greater superficial petrosal nerve.

The tympanic branch of the glossopharyngeal (Jacobson's nerve) enters the tympanic cavity by the inferior tympanic canaliculus, and divides into branches which ramify on the promontory and enter into the formation of the tympanic plexus. The superior and inferior carotico-tympanic nerves, from the carotid plexus of the sympathetic, pass through the wall of the carotid canal, and join the filaments of the tympanic branch of the glossopharyngeal. The branch to the greater superficial petrosal passes through an opening on the labyrinthine wall, in front of the fenestra vestibuli. The smaller superficial petrosal nerve, from the otic ganglion, passes backwards through a foramen in the middle fossa of the base of the skull (sometimes through the foramen ovale), and enters the anterior surface of the petrous part of the temporal bone through a small aperture, situated laterally to the hiatus of the facial canal; it courses downwards through the bone, past the genicular ganglion of the facial nerve, receiving a connecting filament from it, and enters

the tympanic cavity, where it communicates with the tympanic branch of the glossopharyngeal, and assists in forming the tympanic plexus.

The *branches of distribution* of the tympanic plexus are supplied to the mucous membrane of the tympanic cavity; a branch passes to the fenestra vestibuli, another to the fenestra cochleæ, and a third to the auditory tube. The smaller superficial petrosal nerve may be looked upon as the continuation of the tympanic branch of the glossopharyngeal nerve through the tympanic plexus to the otic ganglion.

In addition to the tympanic plexus there are the nerves supplying the muscles. The Tensor tympani is supplied by a branch from the mandibular nerve through the otic ganglion, and the Stapedius by a branch from the facial nerve.

The *chorda tympani nerve* crosses the tympanic cavity. It is given off from the sensory part of the facial nerve, about 6 mm. before that nerve emerges from the stylo-mastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through the *iter chordæ posterius*, and becomes invested with mucous membrane. It traverses the tympanic cavity, crossing medially to the tympanic membrane and over the upper part of the manubrium of the malleus to the carotid wall, where it emerges through the *iter chordæ anterior*, or canal of Huguier.

Applied Anatomy.—Fractures of the middle fossa of the base of the skull almost invariably involve the tympanic roof, and are accompanied by a rupture of the tympanic membrane or fracture through the roof of the bony meatus. They are associated with profuse continued bleeding from the ear, and, if the dura has also been lacerated, with discharge of copious amounts of cerebrospinal fluid. Here the avoidance of infection from the outside is of the utmost importance, as should it occur septic meningitis must inevitably follow with a fatal issue.

The tympanic cavity is very frequently the seat of disease, both suppurative and non-suppurative, and in practically every case the inflammation spreads upwards from the nose or throat along the auditory tube. Acute inflammatory troubles spreading up to the tympanic cavity are usually associated with so much inflammatory swelling of the mucous membrane of the auditory tube as to occlude it, and thus the products of inflammation are pent up in the tympanic cavity and directly involve the tympanic antrum. Under such circumstances the only means of escape for the products is by rupture of the tympanic membrane which usually occurs spontaneously and is followed by a free discharge of pus, with relief to the acute pain which exists in this condition. Should the swelling of the walls of the auditory tube then subside, the normal drainage of the cavity will be established and the perforation in the drum will heal, but if not—as is often the case because the opening of the tube may be occluded by adenoid growths in the nasopharynx or other cause—the pus will continue to accumulate in the middle ear and will overflow through the perforation as a chronic otorrhœa. In the course of time the disease spreads beyond the mucous membrane to the walls of the tympanic cavity, to the ossicles, or to the mastoid process, and when this has occurred the condition is incurable except by the removal of the carious bone. Further, severe intracranial complications are at this time often produced owing to purulent material being retained; thus an abscess may form between the bone and dura mater, (a) about the roof of the tympanic cavity, and immediately beneath the dura covering the temporal lobe, or (b) between the deep aspect of the mastoid process and the sigmoid bend of the transverse sinus, possibly extending widely and surrounding the sinus. In this latter type of case thrombosis of the transverse sinus readily occurs, and the clot being also infected tends to disintegrate and be carried into the general circulation, particles becoming lodged in the capillaries of the lungs and setting up abscesses therein. Pyæmia from transverse sinus thrombosis is more common than from any other focus of origin. In addition, bone disease of the tympanic cavity or antrum may be associated with severe and fatal septic meningitis, or with the formation of abscess in the brain, the most common sites being the temporal lobe and the hemisphere of the cerebellum.

Less serious, but more common, is the formation of a subperiosteal mastoid abscess with great swelling behind the ear, and protrusion outwards of the auricle; such a condition demands an early incision through all the structures, including the periosteum, over the whole length of the mastoid process, and then it will frequently be found that the underlying bone is carious or that a track leads through the bone into the tympanic antrum. In such conditions extensive operations for the removal of bone are often required. In many cases of chronic bone disease in the tympanic cavity, the facial nerve becomes exposed as it lies in its canal, and an inflammatory process is set up in the nerve, leading to facial paralysis of the infranuclear type (p. 871). In other cases localised areas of bone disease, most often in the region of the epitympanic recess, form the points from which aural polypi grow, and the ear polypus, like the nasal polypus, must be considered to have originated in a spot of carious bone, the removal of which is necessary if a cure is to be established.

Of the non-suppurative conditions which affect the middle ear, chronic catarrh, leading to sclerosis of the whole of the tympanic contents, is again due to spread of inflammation from some nasal or pharyngeal condition. The progress is very slow, but leads to ever-increasing deafness—this deafness in the first instance is in no way connected with any defect in the acoustic nerve, and this can be shown by the fact that the hearing by bone conduction over the mastoid process remains normal. In chronic non-suppurative otitis

media; treatment must be especially directed towards placing the nose and pharynx in a healthy condition; when this has been accomplished, the aural condition often improves of itself; if not, improvement may be induced by forcing air up the auditory tube by means of the Politzer bag, or directly into the office of the tube by means of a catheter.

INTERNAL EAR, OR LABYRINTH

The internal ear is the essential part of the organ of hearing, receiving the ultimate distribution of the auditory nerve. It is called the labyrinth, from the complexity of its shape, and consists of two parts: the *osseous labyrinth*, a series of cavities within the petrous part of the temporal bone, and the *membranous labyrinth*, a series of communicating membranous sacs and ducts, contained within the bony cavities.

THE OSSEOUS LABYRINTH (figs. 911, 912)

The *osseous labyrinth* consists of three parts: the *vestibule*, *semicircular canals*, and *cochlea*. These are cavities hollowed out of the substance of the

FIG. 911.—The right osseous labyrinth. Lateral view.



bone, and lined by periosteum; they contain a clear fluid, the perilymph, in which the membranous labyrinth is placed.

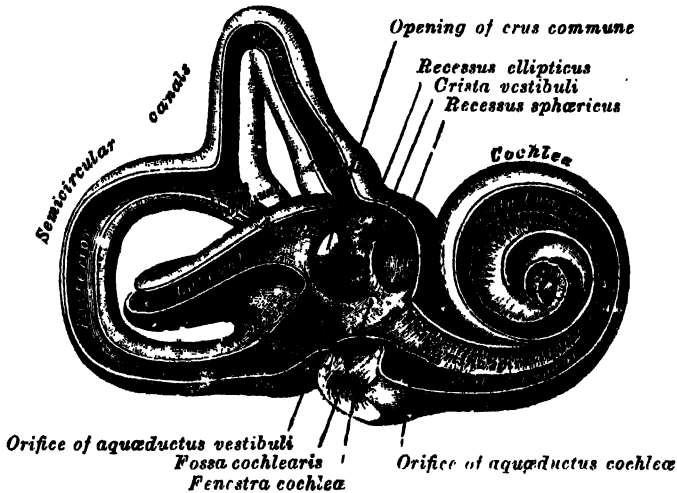
The *vestibule* is the central part of the osseous labyrinth, and is situated medially to the tympanic cavity, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoid in shape, but flattened transversely; it measures about 5 mm. from before backwards, the same from above downwards, and about 3 mm. across. In its *lateral or tympanic wall* is the *fenestra vestibuli*, closed in the recent state by the base of the stapes and its annular ligament. At the front part of the *medial wall* is a small circular depression, the *recessus sphaericus*, which is perforated at its anterior and inferior part by several minute holes (*macula cribrosa media*) for the passage of filaments of the acoustic nerve to the sacculus. Behind this recess is an oblique ridge, the *crista vestibuli*, the anterior end of which is named the *pyramid of the vestibule*; this ridge divides below to enclose a small depression, the *fossa cochlearis*, which is perforated by a number of holes for the passage of filaments of the acoustic nerve to the vestibular end of the ductus cochlearis. At the hinder part of the medial wall is the orifice of the *aqueductus vestibuli*. This aqueduct extends to the posterior surface of the petrous portion of the temporal bone; it transmits a small vein, and contains a tubular prolongation of the membranous labyrinth, the *ductus endolymphaticus*. On the *upper wall or roof* is a transversely elliptical depression, the *recessus ellipticus*, separated anteriorly from the recessus sphaericus by the *crista vestibuli* already mentioned. The pyramid and adjoining part of the recessus ellipticus are perforated by a number of

holes (*macula cribrosa superior*); the holes in the pyramid transmit the nerves to the utricle, and those in the recessus ellipticus the nerves to the ampullæ of the superior and lateral semicircular ducts. Behind are the five orifices of the semicircular canals. In front is an elliptical opening which communicates with the scala vestibuli of the cochlea.

The bony semicircular canals are three in number, superior, posterior, and lateral, and are situated above and behind the vestibule. They are compressed from side to side, and each describes the greater part of a circle. They are unequal in length, but each measures about 0.8 mm. in diameter and presents a dilatation at one end, called the *ampulla*, the diameter of which is more than twice that of the canal. They open into the vestibule by five orifices, one of the apertures being common to two of the canals.

The *superior semicircular canal*, 15 to 20 mm. in length, is vertical in direction, and is placed transversely to the long axis of the petrous portion of the temporal bone, on the anterior surface of which its arch forms a round projection. It describes about two-thirds of a circle. Its lateral extremity is ampullated,

FIG. 912.—The interior of the right osseous labyrinth.



and opens into the upper part of the vestibule; the opposite end joins with the upper end of the posterior canal to form the *crus commune*, which opens into the upper and medial part of the vestibule.

The *posterior semicircular canal*, also vertical, is directed backwards, nearly parallel to the posterior surface of the petrous bone; it is from 18 mm. to 22 mm. long; its lower or ampullated end opens into the lower and posterior part of the vestibule, where are seen several small holes (*macula cribrosa inferior*) for the transmission of the nerves to this ampulla. Its upper end opens into the *crus commune* already mentioned.

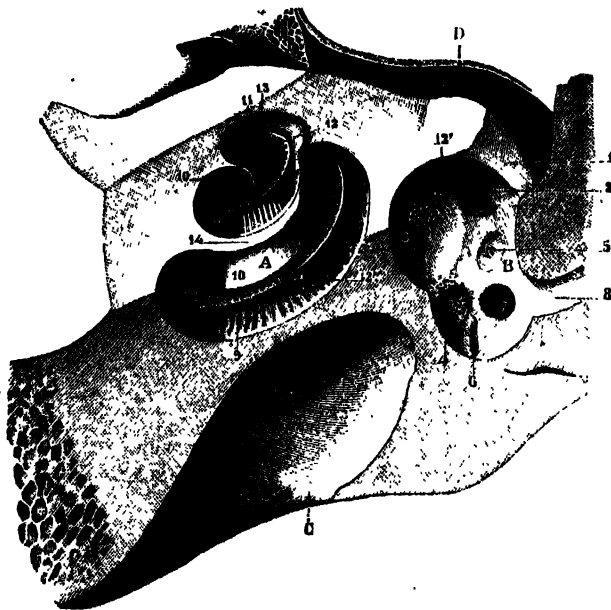
The *lateral or horizontal canal* is from 12 mm. to 15 mm. long, and its arch is directed horizontally backwards and lateralwards. The ampullated end of this canal corresponds to the upper and lateral angle of the vestibule, just above the fenestra vestibuli, where it opens close to the ampullated end of the superior canal; its opposite end opens at the upper and posterior part of the vestibule, below the opening of the *crus commune*.

The lateral semicircular canal of one ear is very nearly in the same plane as that of the other; while the superior canal of one ear is nearly parallel to the posterior canal of the other; thus each semicircular canal stands at right angles to the other two.

The *cochlea* (figs. 912, 913) bears a resemblance to the shell of the common snail; it forms the anterior part of the labyrinth, is conical in form, and placed in front of the vestibule; it measures about 5 mm. from base to apex, and its breadth across the base is about 9 mm. Its apex (cupula) is directed

forwards and lateralwards, with a slight inclination downwards, towards the upper and front part of the labyrinthic wall of the tympanic cavity; its base corresponds with the bottom of the internal acoustic meatus, and is perforated by numerous apertures for the passage of the cochlear nerve. The cochlea * consists of a conical-shaped central axis, the *modiolus*; of a canal, wound spirally around the central axis for two turns and three-quarters; and of a delicate lamina, the *osseous spiral lamina*, which projects from the modiolus into the canal, and partially subdivides it. In the recent state the subdivision of the canal is completed by the *basilar membrane* which stretches from the free border of the bony lamina to the outer wall of the bony cochlea; the two passages into which the cochlear canal is thus divided communicate with each other at the apex of the modiolus by a small opening, named the *helicotrema*.

FIG. 913.—The cochlea and vestibule, viewed from above. (Testut.)



All the hard parts which form the roof of the internal ear have been removed with the saw. A. Cochlea. B. Vestibule. C. Internal acoustic meatus. D. Tympanic cavity. 1. Section of promontory. 2. Fissura vestibuli. 3. Recessus sphericus. 4. Recessus ellipticus. 5. Fossa cochlearis. 6. Orifice of the aqueductus vestibuli. 7. Inferior opening of the posterior semicircular canal. 8. Non-amputated end of lateral semicircular canal. 9. Scala tympani of the cochlea. 10. Scala vestibuli. 11. Cupula. 12. Lamina spiralis ossea, with 12', its vestibular origin; 12'', its external border. 13. Helicotrema. 14. Bony wall of cochlea.

The *modiolus* is the conical central axis or pillar of the cochlea. Its base is broad, and appears at the bottom of the internal acoustic meatus, where it corresponds with the tractus spiralis foraminosus which is perforated by numerous orifices, for the transmission of the branches of the cochlear nerve; the nerves for the first turn and a half of the cochlea pass through the foramina of the tractus spiralis foraminosus; those for the apical turn, through the foramen centrale. The canals of the tractus spiralis foraminosus pass up through the modiolus and successively bend outwards to reach the attached margin of the lamina spiralis ossea. Here they become enlarged, and by their apposition form the *spiral canal of the modiolus*, which follows the course of the attached margin of the osseous spiral lamina and lodges the spiral ganglion (ganglion of Corti). The foramen centrale is continued into a canal which runs up the middle of the modiolus to its apex. The modiolus diminishes rapidly in size in the second and succeeding coil.

The bony canal of the cochlea takes two turns and three-quarters round the modiolus. It is about 30 mm. in length, and diminishes gradually in diameter from the base to the summit, where it terminates in the *cupula*, which forms the

* In the description which follows the cochlea is supposed to be resting on its base.

apex of the cochlea. The beginning of this canal is about 3 mm. in diameter ; it diverges from the modiolus towards the tympanic cavity and vestibule, and presents three openings. One, the *fenestra cochleæ*, communicates with the tympanic cavity and in the recent state is closed by the *secondary tympanic membrane* ; another, of an elliptical form, opens into the vestibule. The third is the aperture of the aqueductus cochleæ, leading to a minute funnel-shaped canal which opens on the inferior surface of the petrous part of the temporal bone and transmits a small vein, and also forms a communication between the subarachnoid cavity and the scala tympani.

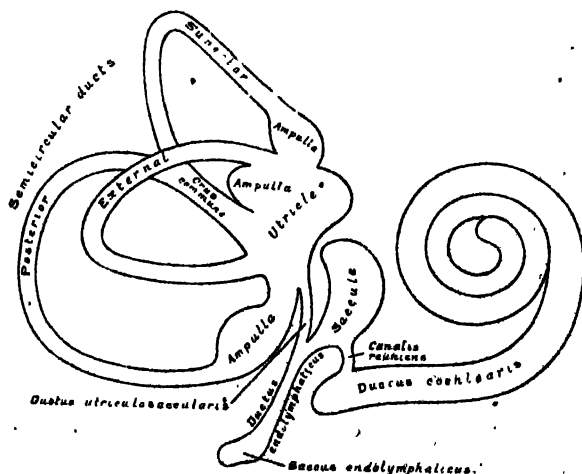
The *osseous spiral lamina* is a bony shelf or ledge which winds round and projects from the modiolus into the interior of the canal, like the thread of a screw. It reaches about halfway across the canal, and incompletely divides it into two passages or *scalæ* : an upper, named the *scala vestibuli*, and a lower, the *scala tympani*. Near the summit of the cochlea the osseous spiral lamina ends in a hook-shaped process, the *hamulus laminae spiralis* ; this assists in forming the boundary of a small opening, the *helicotrema*, through which the two *scalæ* communicate with each other. From the spiral canal of the modiolus numerous canals pass outwards through the osseous spiral lamina as far as its free edge and transmit branches of the cochlear nerve. In the lower part of the first turn of the cochlea a *secondary spiral lamina* projects inwards from the outer wall of the bony tube ; it does not, however, reach the osseous spiral lamina, so that if the laminae be viewed from the vestibule a narrow fissure, the *fissura vestibuli*, is seen between them.

The *ossecus labyrinth* is lined by a thin fibroserous membrane which is closely adherent to the bone ; the free surface of the membrane is smooth and pale, covered with a layer of epithelium, and secretes a thin, limpid fluid, the *perilymph*. A tubular process of this membrane is prolonged through the aqueductus vestibuli to the inner surface of the dura mater.

THE MEMBRANOUS LABYRINTH (figs. 914, 915, 916)

The *membranous labyrinth* is lodged within the bony labyrinth ; it is filled with fluid named *endolymph*, and in its walls the branches of the acoustic

FIG. 914.—The membranous labyrinth. (Schematic.) (Enlarged.)

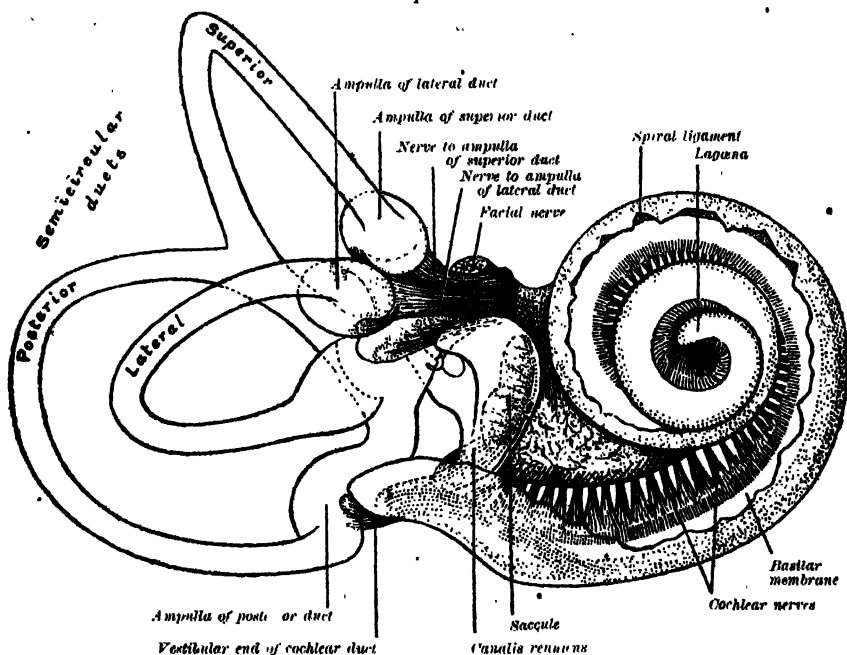


nerve are distributed. It consists of : (a) two small sacs, the *utricle* and *sacculus*, lodged in the vestibule ; (b) three *semicircular canals*, enclosed within the *semicircular canals* ; and (c) the *ductus cochlearis*, contained within the bony cochlea. The various parts of the membranous labyrinth communicate with one another ; the semicircular ducts open into the utricle, the utricle into the saccule through the ductus endolymphaticus, and the saccule into the ductus cochlearis through the *canalis reuniens of Hansen*.

The membranous labyrinth is fixed at certain points to the wall of the bony labyrinth, but is separated from the greater part of the bony labyrinth by a perilymphatic space which contains a fluid named *perilymph*. The perilymphatic space of the vestibule communicates behind with that of the semicircular canals, and opens anteriorly into the scala vestibuli of the cochlea, which in turn opens into the scala tympani through the helicotrema, at the apex of the cochlea. The scala tympani is separated from the tympanic cavity by the secondary tympanic membrane, but is continuous with the subarachnoid cavity through the aqueductus cochleæ.

The utricle, the larger of the two vestibular sacs, is irregularly oblong in shape, compressed transversely, and occupies the upper and posterior part of the vestibule, lying in contact with the recessus ellipticus and the part below it. That portion which is lodged in the recessus ellipticus forms a sort of pouch

FIG. 915.—The right membranous labyrinth of a fifth-month human embryo. $\times 10$. Anterolateral aspect. (G. Retzius.)



or cul-de-sac; the floor and anterior wall of this are thickened, and form the *macula acustica utricle*, which receives the utricular filaments of the acoustic nerve. The cavity of the utricle communicates behind with the semicircular ducts by five orifices. From its anteromedial part a fine canal, the *ductus utriculosaccularis*, is given off, and opens into the ductus endolymphaticus.

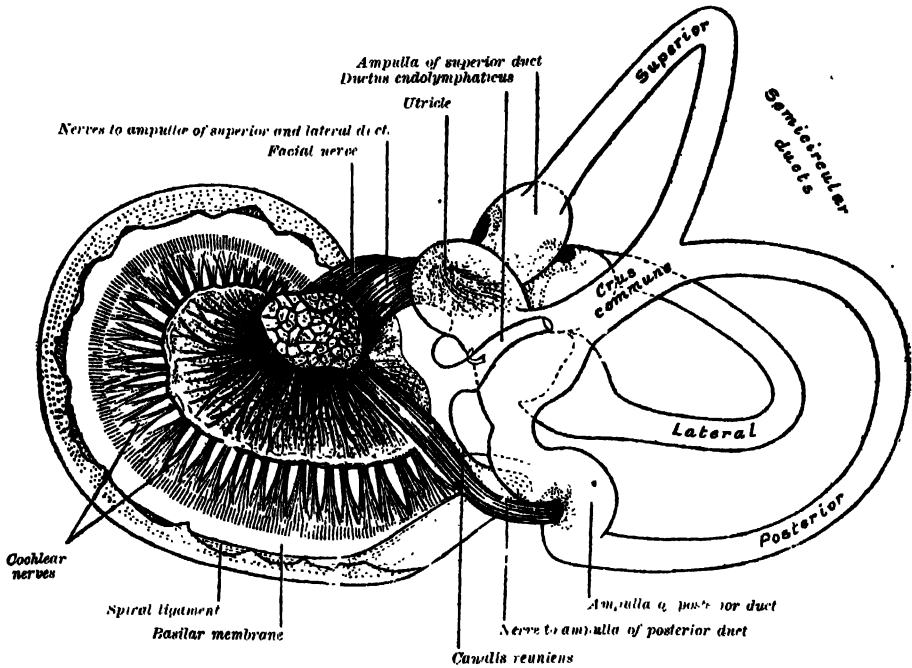
The *sacculus* is globular in form, and lies in the recessus sphaericus near the opening of the scala vestibuli of the cochlea. Its anterior part exhibits an oval thickening, the *macula acustica saccule* (fig. 918), to which are distributed the saccular filaments of the acoustic nerve. Its cavity does not directly communicate with that of the utricle. From its posterior part a canal, the *ductus endolymphaticus*, is given off; this duct is joined by the ductus utriculosaccularis, and then passes along the aqueductus vestibuli and ends in a blind pouch (*sacculus endolymphaticus*), under the dura mater on the posterior surface of the petrous portion of the temporal bone. From the lower part of the sacculus a short tube, the *canalis reuniens* of Hensen, passes downwards and opens into the ductus cochlearis near its vestibular extremity (fig. 914).

The *semicircular ducts* (figs. 915, 916) are about one-fourth of the diameter of the osseous semicircular canals, but in number, shape, and general form they are precisely similar, and each presents at one end an ampulla.

They open by five orifices into the utricle, one opening being common to the medial end of the superior and the upper end of the posterior duct. In each of the ampullæ the wall is thickened, and projects into the cavity as a transverse elevation shaped somewhat like the figure 8, and named the *septum transversum*; the most prominent part of this septum is termed the *crista ampullaris* in which the nerves end.

The utricle, saccule, and semicircular ducts are held in position by numerous fibrous bands which stretch across the perilymphatic space to the bony walls.

FIG. 916.—The right membranous labyrinth of a fifth-month human embryo. $\times 10$. Posteromedial aspect. (G. Retzius.)



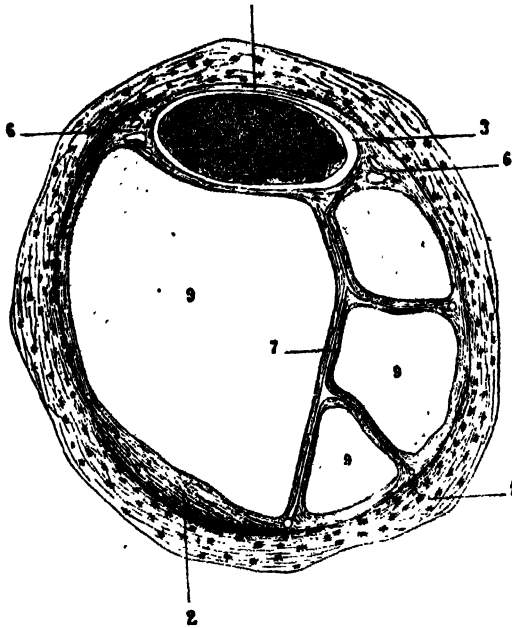
Structure (fig. 917).—The walls of the utricle, saccule, and semicircular ducts consist of three layers. The *outer layer* is composed of ordinary fibrous tissue containing blood-vessels and some pigment-cells. The *middle layer*, thicker and more transparent, is named the *tunica propria*, and presents on its internal surface, especially in the semicircular ducts, numerous papilliform projections, which on the addition of acetic acid, exhibit an appearance of longitudinal fibrillation. The *inner layer* is formed of polygonal nucleated epithelial cells. In the maculæ of the utricle and saccule (fig. 918), and in the cristæ ampullares of the semicircular ducts, the middle coat is thickened and the epithelium is columnar, and consists of *supporting cells* and *hair-cells*. The supporting cells are fusiform, and their deep ends are attached to the membrana propria, while their free extremities are united to form a thin cuticle. The hair-cells are flask-shaped, and their deep, rounded ends do not reach the membrana propria, but lie between the supporting cells. The deep part of each hair-cell contains a large nucleus, while its more superficial part is granular and pigmented. The free end of the cell is surmounted by a long, tapering, hair-like filament, which projects into the cavity. The filaments of the vestibular nerve, having pierced the tunica propria, lose their medullary sheaths, and their axis-cylinders split up into fine fibrils which end between the hair-cells.

Two small rounded bodies termed *otoconia*, consisting of crystals of carbonate of lime, are suspended in the endolymph in contact with the free ends of the hairs projecting from the maculæ.

The *ductus cochlearis* or *scala media* consists of a spirally arranged tube enclosed in the bony canal of the cochlea and lying along its outer wall.

As already stated (p. 996) the osseous spiral lamina extends only part of the distance between the modiolus and the outer wall of the cochlea, while the *basilar membrane* stretches from the free edge of the lamina to the outer wall of the cochlea, and completes the roof of the *scala tympani*. A second

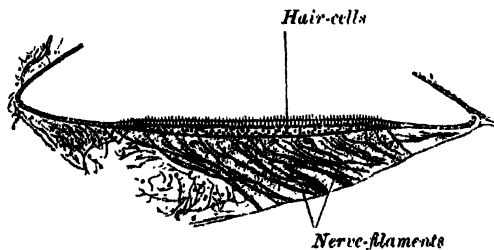
FIG. 917.—A transverse section of a human semicircular canal and duct (after Rüdinger). (Testut.)



1. Semicircular canal. 2. Periosteum. 3. Semicircular duct, with 4, papilliform processes on its internal surface. 5. Connective tissue binding the duct to the periosteum. 6, 6. Fibrous bands uniting the free surface of the duct to the periosteum. 7. Vessels. 8. Endolymphatic space. 9, 9. Perilymphatic space.

and more delicate membrane, the *vestibular membrane* (*Reissneri*) extends from the thickened periosteum covering the osseous spiral lamina to the outer wall of the cochlea, where it is attached at some little distance above the outer edge of the basilar membrane. A canal is thus shut off between the *scala tympani* below and the *scala vestibuli* above; this is the *ductus cochlearis* or *scala media* (figs. 919, 920). It is triangular on transverse section, its roof

FIG. 918.—A transverse section of the macula acustica sacculi. (Retzius.)

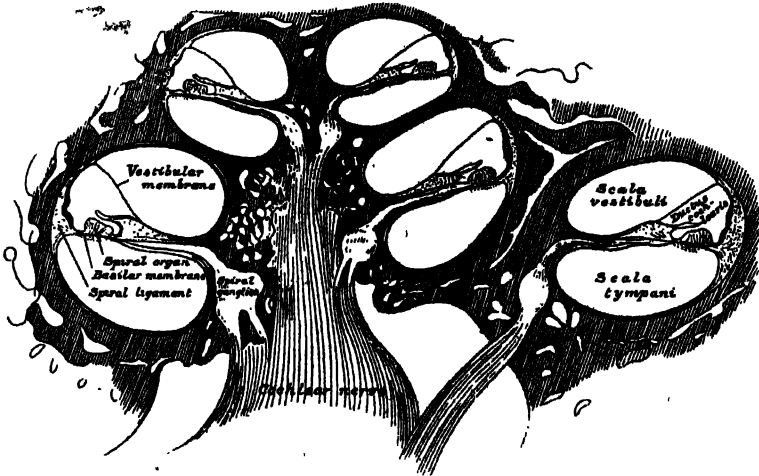


being formed by the vestibular membrane, its outer wall by the periosteum lining the bony canal, and its floor by the membrana basilaris and the outer part of the lamina spiralis ossea. Its extremities are closed; the upper, termed the *lagena*, is attached to the cupula cochleæ and partly bounds the helicotrema;

1000 ORGANS OF THE SENSES AND COMMON INTEGUMENT

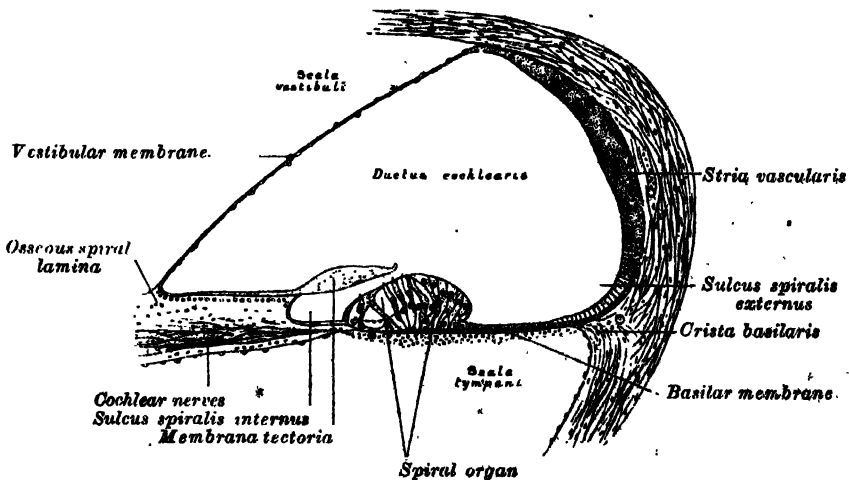
the lower is lodged in the recessus cochlearis of the vestibule. Near the lower extremity the ductus cochlearis communicates with the sacculæ by the narrow, short *canalis reuniens* of Hensen (fig. 914). On the *membrana basilaris* is situated the spiral organ of Corti. The vestibular membrane is thin and

FIG. 919.—A diagrammatic longitudinal section of the cochlea.



homogeneous, and is covered on its upper and under surfaces by a layer of flattened epithelium. The periosteum forming the outer wall of the ductus cochlearis is greatly thickened and altered in character. It projects inwards inferiorly as a triangular prominence, the *crista basilaris*, to which the outer edge of the basilar membrane is fixed; immediately above this is a concavity,

FIG. 920.—A transverse section across the middle coil of the ductus cochlearis. (Retzius.)

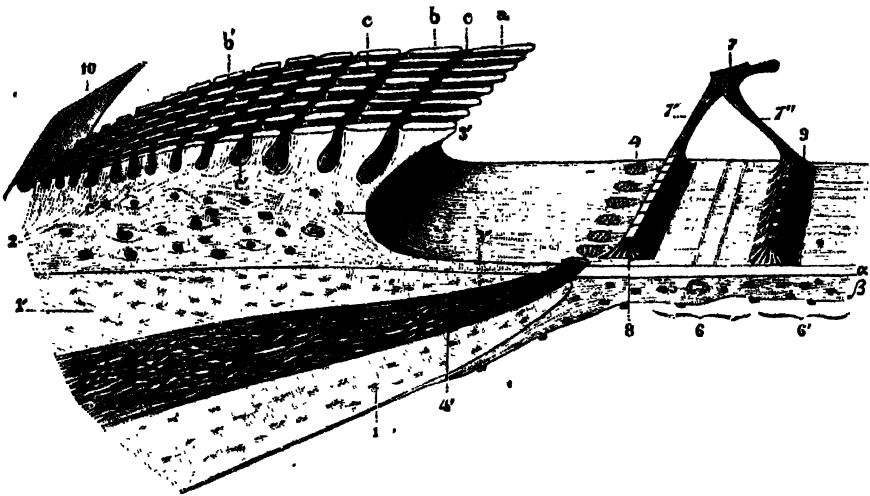


the *sulcus spiralis externus*, above which the periosteum contains numerous blood-vessels, and is termed the *stria vascularis*.

The osseous spiral lamina consists of two plates of bone, and between these are the canals for the transmission of the filaments of the acoustic nerve. On the upper plate of that part of the lamina which is contained within the

ductus cochlearis the periosteum is thickened to form the *limbus laminae spiralis* (fig. 921); this ends externally in a concavity, the *sulcus spiralis internus*, which represents, on section, the form of the letter C; the upper part, formed by the overhanging edge of the limbus, is named the *vestibular lip*; the lower part, prolonged and tapering, is called the *tympanic lip*, and is perforated by numerous foramina for the passage of the branches of the cochlear nerve. The upper surface of the vestibular lip is intersected at right angles by a number of furrows, between which are numerous elevations; these present the appearance of teeth on the free surface and margin of the lip, and were named by Huschke the *auditory teeth* (fig. 921). The limbus is covered by a layer of what appears to be squamous epithelium, but only the cells covering the teeth are flattened, those in the furrows being columnar, and

FIG. 921.—The limbus laminae spiralis and the membrana basilaris. (Schematic.) (Testut.)



1, 1'. Upper and lower lamellae of the lamina spiralis ossea. 2. Limbus laminae spiralis, with *a*, the auditory teeth of the first row; *b*, *b'*, the teeth of the other rows; *c*, *c'*, the grooves between the auditory teeth and the cells which are lodged in them. 3. Sulcus spiralis internus, with 3', its labium vestibulare, and 3'', its labium tympanicum. 4. Foramina nervosa, giving passage to the nerves from the spiral ganglion of Corti. 5. Vas spirale. 6. Zona arcuata, and 6', zona pectinata of the basilar membrane, with *a*, its hyaline layer, *β*, its connective tissue layer. 7. Summit of the tunnel of Corti, with 7', its inner rod, and 7'', its outer rod. 8. Bases of the inner rods, from which the cells are removed. 9. Bases of the outer rods. 10. Part of the vestibular membrane.

occupying the intervals between the elevations. This layer of epithelium is continuous on the one hand with that lining the sulcus spiralis internus, and on the other with that covering the under surface of the vestibular membrane.

Basilar membrane.—The basilar membrane stretches from the tympanic lip of the osseous spiral lamina to the basilar crest. Its width increases from 0.21 mm. in the basal turn to 0.36 mm. in the apical turn of the cochlea. Its inner part is thin, and is named the *zona arcuata*; it supports the spiral organ of Corti; the outer part is thicker and striated, and is termed the *zona pectinata*. The under surface of the membrane is covered by a layer of vascular connective tissue; one of the vessels in this tissue is somewhat larger than the rest, and is named the *vas spirale*; it lies below Corti's tunnel.

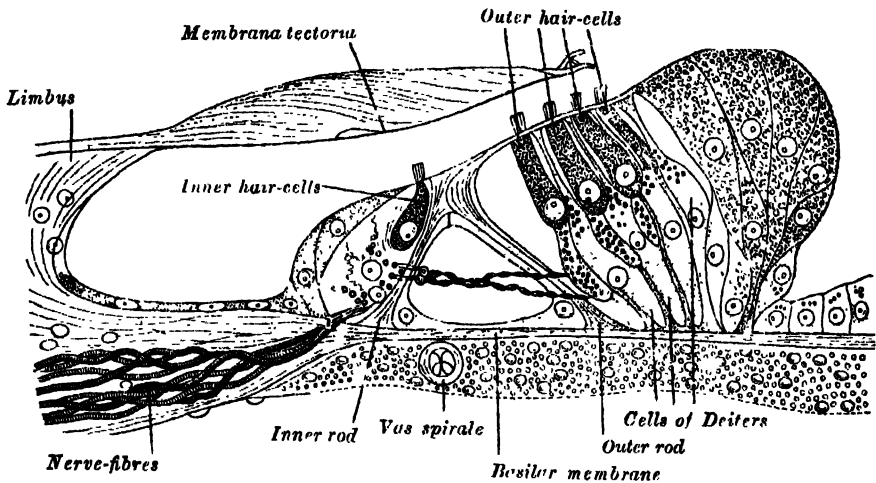
The spiral organ of Corti (figs. 920, 922) is composed of a series of epithelial structures placed upon the inner part of the basilar membrane. The more central of these structures are two rows of rod-like bodies, the *inner and outer rods* or *pillars of Corti*. The bases of the rods are supported on the basilar membrane, those of the inner row at some distance from those of the outer; the two rows incline towards each other and, coming into contact above, enclose between them and the basilar membrane the *tunnel of Corti*, which is triangular in cross section. On the inner side of the inner rods is a single row of hair-cells, and on the outer side of the outer rods three or four rows of hair-cells, together with certain supporting cells.

of Hensen. The free ends of the outer hair-cells occupy a series of apertures in a net-like membrane, the reticular membrane, and the entire organ is covered by the tectorial membrane.

Rods of Corti.—Each of these consists of a base or foot-plate, an elongated part or body, and an upper end or head; the body of each rod is finely striated, but in the head there is an oval non-striated portion which stains deeply with carmine. Occupying the angles between the rods and the basilar membrane are nucleated cells which partly envelop the rods and extend on to the floor of Corti's tunnel; these may be looked upon as the undifferentiated parts of the cells from which the rods have been formed.

The *inner rods* number nearly 6000, and their bases rest on the basilar membrane close to the tympanic lip of the sulcus spiralis internus. The shaft or body of each is sinuously curved and forms an angle of about sixty degrees with the basilar membrane. The head resembles the proximal end of the ulna, and presents a deep concavity which accommodates a convexity on the head of the outer rod. The head-plate, or portion overhanging the concavity, overlaps the head-plate of the outer rod.

FIG. 922.—A transverse section through the spiral organ of Corti. Magnified. (G. Retzius.)



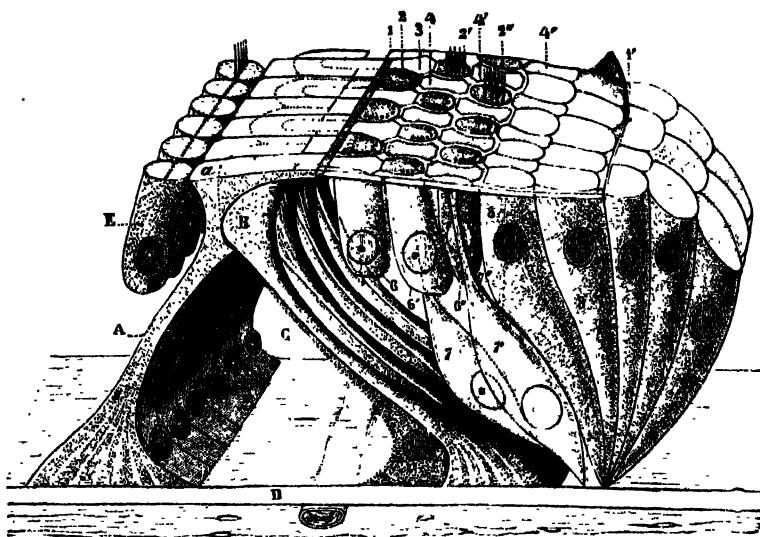
The *outer rods*, nearly 4000 in number, are longer and more obliquely set than the inner, forming with the basilar membrane an angle of about forty degrees. Their heads are convex internally: they fit into the concavities on the heads of the inner rods, and are continued outwards as thin flattened plates, termed *phalangeal processes*, which unite with the phalangeal processes of Deiters' cells to form the reticular membrane.

Hair-cells.—The hair-cells are short columnar cells; their free ends are on a level with the heads of Corti's rods, and each is surmounted by about twenty hair-like processes arranged in the form of a crescent with its concavity directed inwards. The deep ends of the cells reach about halfway along Corti's rods, and each contains a large nucleus; in contact with the deep ends of the hair-cells are the terminal filaments of the cochlear nerve. The *inner hair-cells*, about 3500 in number, are arranged in a single row on the medial side of the inner rods, and, their diameters being greater than those of the rods, each is supported by more than one rod. The free ends of the inner hair-cells are encircled by a cuticular membrane which is fixed to the heads of the inner rods. Adjoining the inner hair-cells are one or two rows of columnar supporting cells, which, in turn, are continuous with the cubical cells lining the sulcus spiralis internus. The *outer hair-cells* number about 12,000, and are nearly twice as long as the inner. In the basal coil of the cochlea they are arranged in three regular rows; in the apical coil, in four somewhat irregular rows.

Between the rows of the outer hair-cells are rows of supporting cells, called the *cells of Deiters*; their expanded bases are planted on the basilar membrane, while the opposite end of each presents a clubbed extremity or *phalangeal* process. Immediately to the outer side of Deiters' cells are five or six rows of columnar cells, the *supporting cells of Hensen*. Their bases are narrow, while their upper parts are expanded and form a rounded elevation on the floor of the ductus cochlearis. The columnar cells lying outside Hensen's cells are termed the *cells of Claudius*. A space exists between the outer rods of Corti and the adjacent hair-cells; this is called the *space of Nuel*.

The *reticular lamina* (fig. 923) is a delicate framework perforated by circular holes which are occupied by the free ends of the outer hair-cells. It extends from the heads of the outer rods of Corti to the external row of the outer hair-cells, and is formed by several rows of minute fiddle-shaped cuticular structures,

FIG. 923.—The lamina reticularis and subjacent structures. (Schematic.) (Testut.)



A. Inner rod of Corti, with *a*, its head. B. Outer rod (in yellow). C. Tunnel of Corti. D. Membrana reticularis. E. Inner hair-cells. 1, 1'. Internal and external borders of the membrana reticularis. 2, 2', 2''. The three rows of circular holes (in blue). 3. First row of phalanges (in yellow). 4, 4', 4''. Second, third, and fourth rows of phalanges (in red). 6, 6', 6''. The three rows of outer hair-cells (in blue). 7, 7', 7''. Cells of Deiters. 8. Cells of Hensen and Claudius.

called *phalanges*, between which are circular apertures containing the free ends of the hair-cells. The innermost row of phalanges consists of the phalangeal processes of the outer rods of Corti; the outer rows are formed by the modified free ends of Deiters' cells.

The *teclorial membrane* overlies the sulcus spiralis internus and the spiral organ of Corti. It is wider and thicker in the apical than in the basal part of the cochlea. Its inner part is thin and is attached to the vestibular lip of the limbus laminae spiralis, the attachment reaching as far as the vestibular membrane. The outer part is thick and padlike, the thickness being greatest over, or slightly to the inner side of the upper ends of Corti's rods. Retzius described the outer edge as being attached to the outer row of Deiters' cells while others maintain that it forms a ragged or frayed margin. Hardesty,* who has examined the membrane in the pig, states that this edge is free and bluntly rounded, but finely and irregularly scalloped. On the under surface of the membrane, opposite the interval between the inner and outer rows of hair-cells is a band, named *Hensen's stripe*.

Hardesty has shown that the membrane "consists of multitudes of delicate fibrils embedded in a transparent matrix of a soft, collagenous, semi-solid character with marked

* *American Journal of Anatomy*, vol. viii.

adhesiveness.* The prevailing course of the fibres is obliquely transverse, slanting from the vestibular lip towards the apex of the cochlea. The fibres pass in curves from the vestibular lip and upper surface of the membrane to its under surface, where by their interlacement they produce the appearance known as Hensen's stripe. He also describes a thin, exceedingly delicate *accessory tectorial membrane*, lying along the under surface of the outer zone of the main membrane, and lightly attached to the latter by its outer edge.

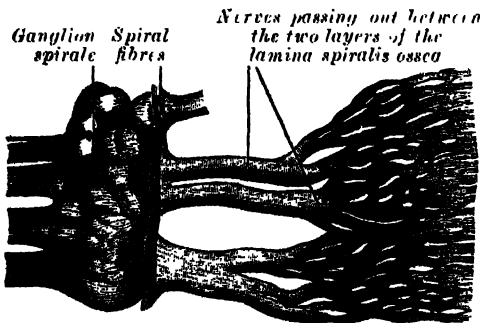
The **acoustic nerve**, or nerve of hearing, divides near the bottom of the internal acoustic meatus into an anterior or cochlear, and a posterior or vestibular portion. The deep connexions of these nerves are described on pp. 872 to 874.

The *vestibular nerve* supplies the utricle, the saccule, and the ampullæ of the semicircular ducts. On the trunk of the nerve, within the internal acoustic meatus, is the *vestibular ganglion* (ganglion of Scarpa), from the nerve-cells of which the fibres of the nerve take origin. On the distal side of the ganglion the nerve splits into a superior, an inferior, and a posterior branch.* The filaments of the *superior branch* are transmitted through the foramina in the area vestibularis superior, and end in the macula of the utricle and in the cristæ of the ampullæ of the superior and lateral semicircular ducts; those of the *inferior branch* traverse the foramina in the area vestibularis inferior, and end in the macula of the saccule. The *posterior branch* runs through the foramen singulare at the postero-inferior part of the bottom of the meatus and divides into filaments for the supply of the crista of the ampulla of the posterior semicircular duct.

The *cochlear nerve* divides into numerous filaments at the base of the modiolus; those for the basal and middle coils pass through the foramina in the tractus spiralis foraminosus, those for the apical coil through the canalis centralis, and the nerves bend outwards and pass between the lamellæ of the osseous spiral lamina. Occupying the spiral canal of the modiolus is the *spiral ganglion of the cochlea* (ganglion of Corti) (fig. 924), consisting of bipolar nerve-cells from which the fibres of the nerve take origin. Reaching the outer edge of the osseous spiral lamina, the nerve-fibres pass through the foramina in the tympanic lip; some end by arborising around the deep ends of the inner hair-cells, while others pass between Corti's rods and across Corti's tunnel, and end

in a similar manner in relation to the outer hair-cells. The cochlear nerve gives off a vestibular branch to supply the vestibular end of the ductus cochlearis; the filaments of this branch traverse the foramina in the fossa cochlearis (p. 993).

FIG. 924.—Part of the cochlear division of the acoustic nerve. Highly magnified. (Henne.)



Vessels. The arteries of the labyrinth are the internal auditory branch of the basilar artery, and the stylo-mastoid branch of the posterior auricular artery. The internal auditory artery divides at the bottom of the internal acoustic meatus into two branches: cochlear and vestibular. The cochlear branch subdivides into

twelve or fourteen twigs, which traverse the canals in the modiolus, and are distributed, in the form of a capillary network, in the lamina spiralis and basilar membrane. The vestibular branches are distributed to the utricle, saccule, and semicircular ducts.

The veins of the vestibule and semicircular canals accompany the arteries, and, receiving the veins of the cochlea at the base of the modiolus, unite to form the internal auditory veins which end in the posterior part of the superior petrosal sinus or in the transverse sinus. A small vein, from the basal turn of the cochlea, traverses the aqueductus cochleæ and joins the internal jugular vein.

Applied Anatomy.—The diseased conditions which may be found in the internal ear usually result from the spread of a suppurative process from the middle ear—thus in

* The nerve sometimes splits on the proximal side of the ganglion, which is then divided into three parts, one on each branch of the nerve. When this occurs the ganglion of the posterior division is placed in the foramen singulare.

chronic suppuration of the latter, destruction of the internal ear may take place, with necrosis of parts of the cochlea or vestibule. Such cases will be associated with 'nerve-deafness,' and the disease may spread by means of the sheaths of the facial and acoustic nerves into the posterior fossa of the skull.

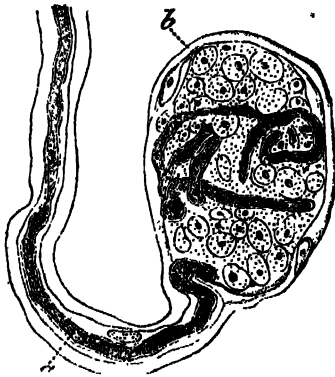
Hæmorrhage occasionally occurs into the labyrinth in certain blood disorders, resulting in complete 'nerve-deafness,' and such conditions may be associated with symptoms known as 'Menière's disease,' vertigo, giddiness, and tinnitus. Nerve-deafness is diagnosed when all 'bone-conduction' of sound is lost, and is most commonly seen in patients suffering from congenital syphilis, many deaf-mutes being the subjects of this condition. It is also not rare after mumps.

PERIPHERAL TERMINATIONS OF NERVES OF GENERAL SENSATIONS

The peripheral terminations of the nerves associated with general sensations (i.e. the muscular sense and the senses of heat, cold, pain, and pressure) are widely distributed throughout the body. These nerves may end as *free fibrils* amongst the tissue elements or in *special end-organs* where the terminal nerve-filaments are enclosed in capsules.

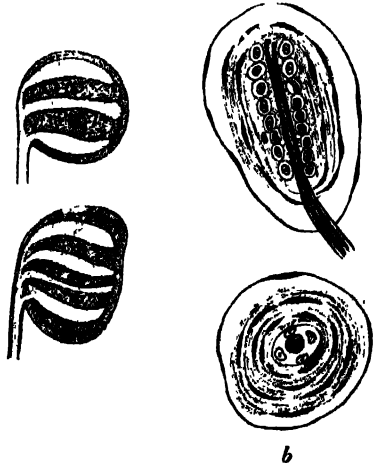
Free nerve-endings occur chiefly in the epidermis and in the epithelium covering certain mucous membranes; they are well seen in the stratified squamous epithelium

FIG. 925.—An end-bulb of Krause. (From Klein's Elements of Histology.)



a. Medullated nerve-fibre. b. Capsule.

FIG. 926.—Tactile corpuscles; (a) of Grandry, (b) of Herbst.



of the cornea, and are also found in the root-sheaths and papillæ of the hairs, and around the bodies of the sudoriferous glands.

When the nerve-fibre approaches its termination, the medullary sheath suddenly disappears, leaving the axis-cylinder surrounded by the neurolemma. After a time the fibre loses its neurolemma, and consists only of an axis-cylinder, which can be seen, in preparations stained with chloride of gold, to be made up of fine varicose fibrillæ. Finally, the axis-cylinder breaks up into its constituent fibrillæ, which often present regular varicosities, and anastomosing with one another, end in small knobs or discs between the epithelial cells.

Under this heading may be classed the *tactile discs* described by Merkel as occurring in the epidermis of the pig's snout, where the fibrillæ of the axis-cylinder end in cup-shaped discs in apposition with large epithelial cells.

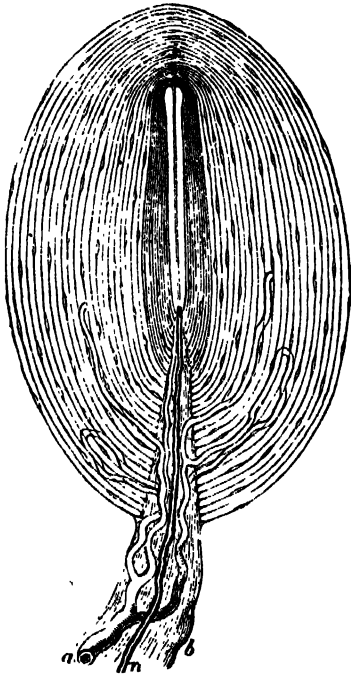
The **special end-organs** exhibit great variety in size and shape, but have one feature in common, viz. the terminal fibrils of the nerve are enveloped by a capsule. Included in this group are the end-bulbs of Krause; the corpuscles of Grandry, of Pacini, of Herbst, of Golgi and Mazzoni, of Wagner and Meissner; and the neurotendinous and neuromuscular spindles.

The **end-bulbs of Krause** (fig. 925) are minute cylindrical or oval bodies, consisting of a capsule of connective tissue enveloping a soft semi-fluid core in which the

axis-cylinder terminates either in a bulbous extremity or in a coiled-up plexiform mass. End-bulbs are found in the conjunctiva of the eye (where they are spheroidal in shape in man, but cylindrical in most other animals), in the mucous membrane of the lips and tongue, and in the epineurium of nerve-trunks. They are also found in the penis and clitoris, and have there received the name of *genital corpuscles*; in these situations they have a mulberry-like appearance, being constricted by connective tissue septa into from two to six knob-like masses. In the synovial strata of certain joints (e.g. those of the fingers), rounded or oval end-bulbs occur, and are designated *articular end-bulbs*.

The *tactile corpuscles of Grandry* (fig 926a) occur in the papillæ of the beak and tongue of ducks and geese. Each consists of a capsule composed of a delicate,

FIG. 927.—A Pacinian corpuscle, with its system of capsules and its central cavity.

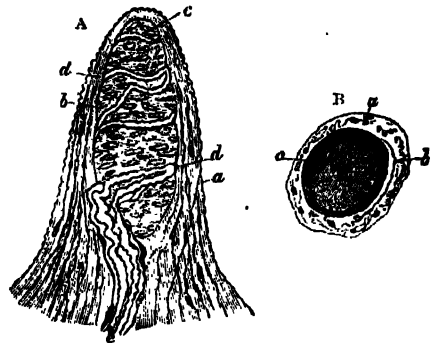


a. Arterial twig, ending in capillaries, which form loops in some of the intercapsular spaces; one penetrates to the central capsule. b. The fibrous tissue of the stalk. c. Nerve-fibre advancing to the central capsule, there losing its medullary sheath, and passing along the core to the opposite end, where it terminates in a tuberculated enlargement.

of these corpuscles is attached to and encloses the termination of a single nerve-fibre. The corpuscle (which is visible to the naked eye and can be most easily demonstrated in the mesentery of a cat) consists of a number of concentric lamellæ or capsules arranged around a central space, in which the nerve-fibre is contained. Each lamella is composed of bundles of fine connective tissue fibres, and is lined on its inner surface by a single layer of flattened epithelioid cells. The central space is elongated or cylindrical in shape, and filled with a transparent core, in the middle of which the axis-cylinder traverses the space to near its distal extremity, where it ends in one or more small knobs. Todd and Bowman have described minute arteries as entering by the sides of the nerves and forming capillary loops in the intercapsular spaces, and even penetrating into the central space.

Herbst has described a nerve-ending somewhat similar to the Pacinian corpuscle, in the mucous membrane of the tongue of the duck; and in some other situations. It differs, however, from the Pacinian corpuscle in being smaller, in its capsules being more closely approximated, and—especially in the fact that the axis-cylinder

FIG. 928.—A papilla of the hand, containing a tactile corpuscle of Wagner and Meissner. $\times 350$.



A. Side view of a papilla. a. Capsule. b. Tactile corpuscle. c. Small nerve of the papilla, with neurolemma. d. Its two nerve-fibres running with spiral coils round the tactile corpuscle. e. Apparent termination of one of these fibres. B. Transverse section of a tactile papilla. a. Capsule. b. Nerve-fibre. c. Outer layer of the tactile corpuscle, with nuclei. d. Clear internal substance.

nucleated membrane, and containing two or more granular, somewhat flattened cells between which the axis-cylinder ends in flattened discs.

The *Pacinian corpuscles* (fig. 927) are found in the subcutaneous tissue on the nerves of the palm of the hand and sole of the foot, and in the genital organs of both sexes; they also occur on the nerves of the joints, and in some other situations, as in the mesentery and pancreas of the cat and along the tibia of the rabbit. Each

in the central clear space is coated with a continuous row of nuclei. These nerve-endings are known as the *corpuscles of Herbst* (fig. 926b).

The *corpuscles of Golgi and Mazzoni* are found in the subcutaneous tissue of the pulp of the fingers. They differ from Pacinian corpuscles in that their capsules are thinner, their contained cores thicker, and in the latter the axis-cylinders ramify more extensively and end in flat expansions.

The *tactile corpuscles of Wagner and Meissner* (fig. 928) are oval-shaped bodies which occur in the papillæ of the corium of the hand and foot, the front of the forearm, the skin of the lips, the mucous membrane of the tip of the tongue, the palpebral conjunctiva, and the skin of the mammary papilla. Each is enveloped by a connective tissue capsule, which sends membranous septa into the interior.

FIG. 929.—A nerve-ending of Ruffini. (Arch. ital. de Biol., Turin, t. xxi. 1894.)

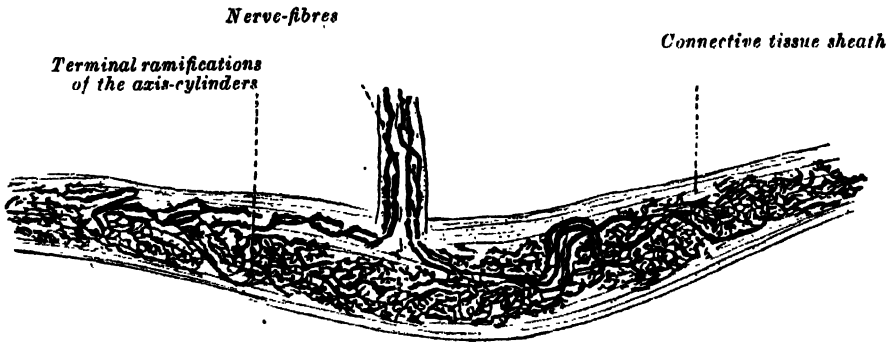
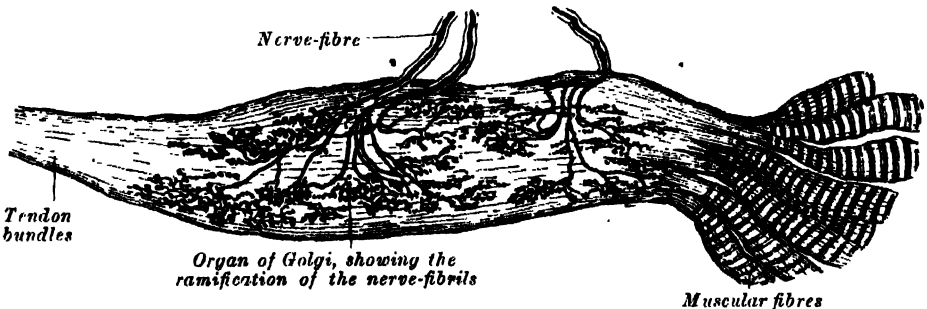


FIG. 930.—A neurotendinous spindle or organ of Golgi from the human tendo calcaneus. (After Ciaccio.)



The axis-cylinder passes through the capsule, and after making several spiral turns round the body of the corpuscle ends in small globular or pear-shaped enlargements.

Corpuscles of Ruffini.—Ruffini described a special variety of nerve-ending in the subcutaneous tissue of the human finger (fig. 929), and mostly situated at the junction of the corium with the subcutaneous tissue. They are oval in shape, and consist of strong connective tissue sheaths, inside which the nerve-fibres divide into numerous branches, which show varicosities and end in small free knobs.

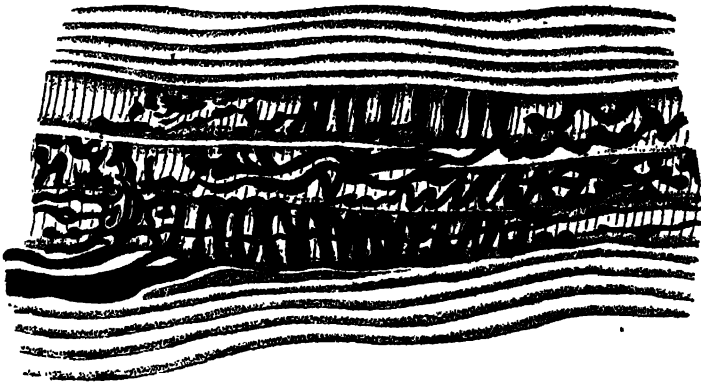
The *neurotendinous spindles* or *organs of Golgi* are chiefly found near the junctions of tendons with muscles. Each is enclosed in a capsule which contains a number of enlarged tendon-fasciculi (*intrafusal fasciculi*). One or more nerve-fibres perforate the side of the capsule and lose their medullary sheaths; the axis-cylinders subdivide and end between the tendon-fibres in irregular discs or varicosities (fig. 930).

The *neuromuscular spindles* are present in the majority of voluntary muscles, and consist of small bundles of peculiar muscular fibres (*intrafusal fibres*), embryonic in type, invested by capsules, within which nerve-fibres, experimentally shown to be

1008 ORGANS OF THE SENSES AND COMMON INTEGUMENT

sensory, terminate. These neuromuscular spindles vary in length from 0.8 mm. to 5 mm. and have a fusiform appearance. The large medullated nerve-fibres passing to the end-organ are from one to three or four in number; entering the fibrous capsule, they divide several times, and, losing their medullary sheaths,

FIG. 931.—The middle third of a terminal plaque in the muscle-spindle of an adult cat. (After Ruffini.)



ultimately end in naked axis-cylinders encircling the intrafusal fibres by flattened expansions, or irregular ovoid or rounded discs (fig. 931). Neuromuscular spindles have not yet been demonstrated in the muscles of the tongue, and only a few exist in the ocular muscles.

THE COMMON INTEGUMENT

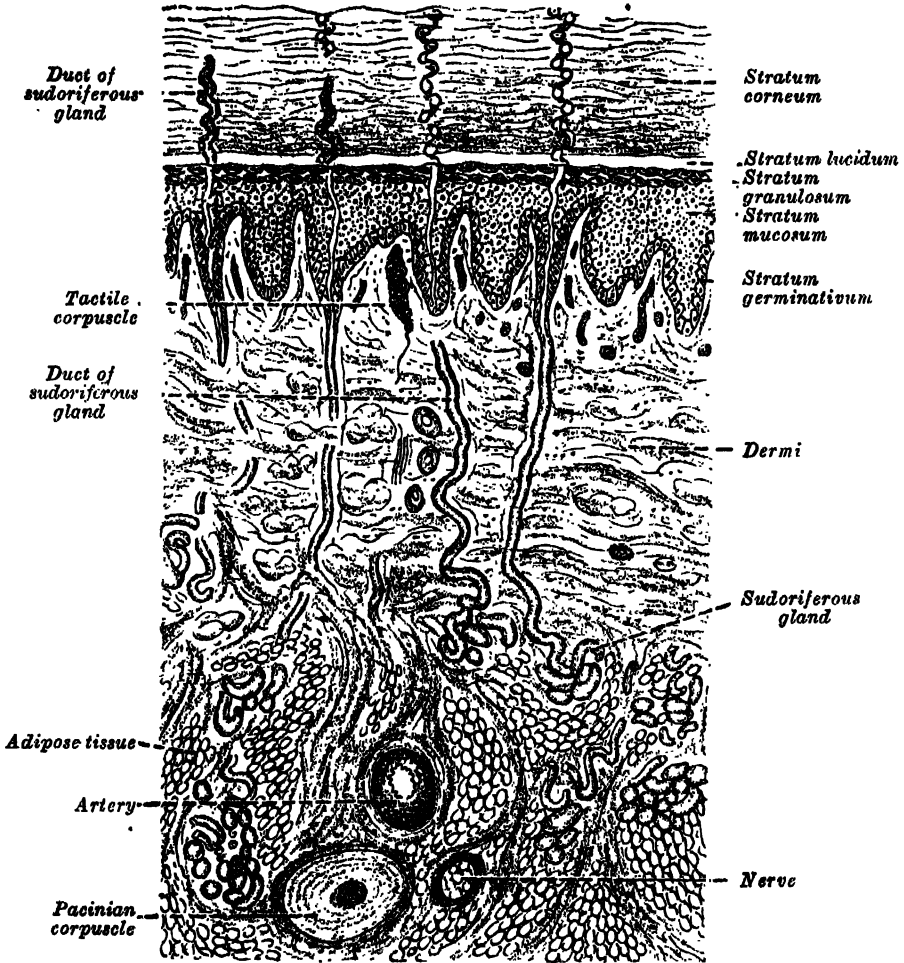
The integument or skin (fig. 932) covers the body and protects the deeper tissues. It contains the peripheral endings of many of the sensory nerves, plays an important part in the regulation of the body temperature, and possesses limited excretory and absorbing powers. It consists principally of a layer of vascular connective tissue, named the *corium* or *cutis vera*, and an external covering of epithelium, termed the *epidermis* or *cuticle*. On the surface of the former layer are sensitive and vascular *papillæ*; and within, or beneath it, are certain organs with special functions: namely, the *sudoriferous* and *sebaceous glands*, and the *hair-follicles*.

The *epidermis* or *cuticle* is non-vascular; it consists of stratified epithelium (fig. 933), and is accurately moulded on the papillary layer of the corium. It varies in thickness in different parts. In some situations, as in the palms of the hands and soles of the feet, it is thick, hard, and horny in texture. This may be in a measure due to the fact that these parts are exposed to intermittent pressure, but that this is not the only cause is proved by the fact that the condition exists to a very considerable extent at birth. The more superficial layers of cells form the *horny layer* (*stratum corneum*), which may be separated by maceration from a deeper stratum, the *stratum mucosum*, consisting of several layers of differently shaped cells. The free surface of the epidermis is marked by a network of linear furrows of variable size, dividing the surface into a number of polygonal or lozenge-shaped areas. These furrows are large opposite the flexures of the joints, and correspond with the folds in the corium produced by movements. In other situations, as upon the back of the hand, they are small, and intersect one another at various angles. Upon the palmar surfaces of the hands and fingers, and upon the soles of the feet, these lines are fine but very distinct, and are disposed in more or less parallel curves; they depend upon the large size and peculiar arrangement of the papillæ upon which the epidermis is placed. In each individual the lines on the tips of the fingers and thumbs form distinct patterns unlike those of any other person. A method of determining the identity of a criminal is based on this fact, impressions ('finger-prints') of these lines being made on paper covered with soot, or on white paper after first covering the fingers with ink. The deep surface of the epidermis is accurately moulded upon the papillary layer of the corium, the papillæ being covered by a basement membrane; so that when the epidermis

is removed by maceration, its under surface presents a number of pits or depressions corresponding with the papillæ, and ridges corresponding with the intervals between them. Fine tubular prolongations are continued from this layer into the ducts of the sudoriferous and sebaceous glands.

The epidermis consists of stratified epithelium which is arranged in five layers named from within outwards as follows: (a) stratum germinativum, (b) stratum mucosum, (c) stratum granulosum, (d) stratum lucidum, and (e) stratum corneum.

FIG. 932.—A diagrammatic section of the skin. Magnified.



The *stratum germinativum* consists of a layer of columnar cells with oblong nuclei. The cells are placed perpendicularly on the basement membrane and attached to it by denticulated extremities.

The *stratum mucosum* is composed of several layers of spherical or polyhedral cells, the contents of which are soft, opaque, and granular. These cells are joined to one another by fine protoplasmic bridges. When the cells are isolated these bridges are broken and the surfaces of the cells are beset with numerous short thorn-like processes which give the cells a characteristic appearance and have led to their being named *prickle-cells*. The cells contain numerous fine fibrils which can be stained by carmine or hæmatoxylin, and are continuous with those of neighbouring cells across the protoplasmic bridges. Between the bridges are minute lymph-channels in which lymph-corpuscles or pigment-granules may be found.

The *stratum granulosum* comprises two or three layers of fusiform cells which contain granules of *eleidin*, a substance readily stained by hæmatoxylin or carmine,

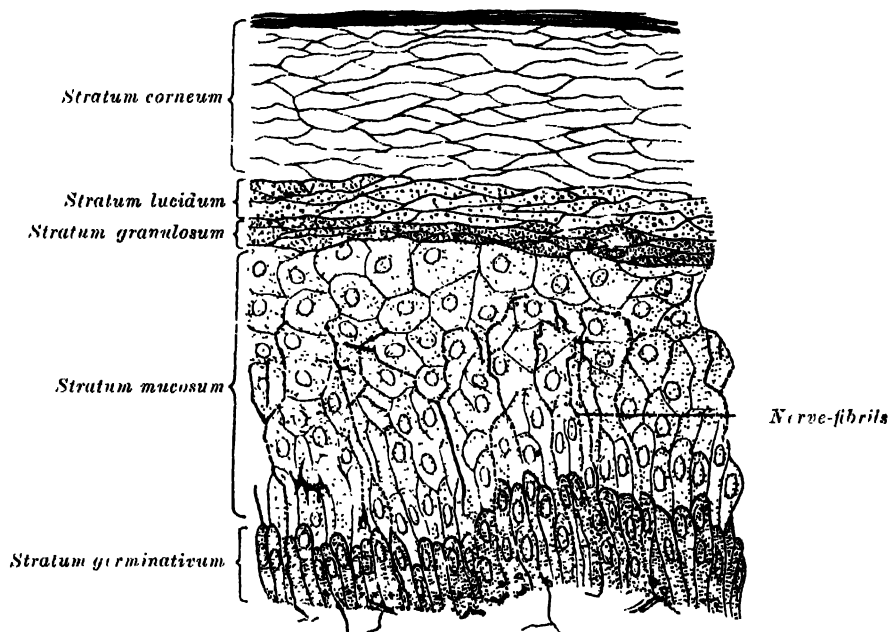
and probably an intermediate stage in the formation of keratin. They are supposed to be cells undergoing transformation from the protoplasmic cells of the stratum mucosum to the horny cells of the superficial layers.

The *stratum lucidum* appears in section as a homogeneous or dimly striated layer, composed of closely packed cells in which traces of flattened nuclei may be found, and in which the eleidin has been changed into a substance named *keratohyalin*.

The *stratum corneum* consists of several layers of horny epithelial cells in which no nuclei are discernible. They are unaffected by acetic acid, and their protoplasm has been converted into a horny material, known as *keratin*. According to Ranvier they contain granules of a material which has the characteristics of beeswax.

The black colour of the skin in the negro and the tawny colour in some of the white races are due to the presence of pigment in the cells of the epidermis. This

FIG. 933.—A section of the epidermis. (Ranvier.)



pigment is more especially distinct in the cells of the stratum mucosum, and is similar to that found in the cells of the pigmentary layer of the retina. As the cells approach the surface and desiccate, the pigment is partially lost.

The *corium* or *cutis vera* is tough, flexible, and highly elastic. It is very thick in the palms of the hands and soles of the feet; thicker on the posterior than on the anterior aspect of the body, and on the lateral than on the medial sides of the limbs. It is exceedingly thin and delicate in the eyelids, scrotum, and penis.

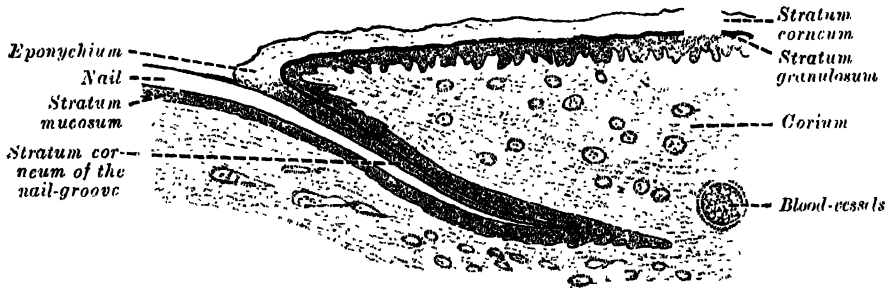
It consists of felted connective tissue, with a varying number of elastic fibres and numerous blood-vessels, lymphatic vessels, and nerves. The connective tissue is arranged in two layers: a deeper or *reticular*, and a superficial or *papillary*. Unstriated muscular fibres are found in the superficial layers of the corium wherever hairs are present; they are also present in the subcutaneous areolar tissue of the scrotum, penis, labia majora, and nipples. In the nipples the fibres are disposed in bands, closely reticulated and arranged in superimposed laminae.

The *reticular layer* consists of strong interlacing bands, composed chiefly of white fibrous tissue, but containing some yellow elastic fibres which vary in number in different parts; the connective tissue corpuscles are often to be found flattened against the bundles of white fibrous tissue. Towards the attached surface the fasciculi are coarse, and the large areolæ left by their interlacement are occupied by adipose tissue and sweat-glands. Below the reticular layer is the subcutaneous areolar tissue, which, except in a few situations, contains fat.

The *papillary layer* consists of numerous highly sensitive and vascular eminences, the *papillæ*, which rise perpendicularly from its surface. The papillæ are minute conical eminences, having round or blunted extremities, occasionally divided into two or more parts, and are received into corresponding pits on the under surface of the cuticle. On the general surface of the body, more especially in parts endowed with slight sensibility, they are few in number, and exceedingly minute; but in some situations, as upon the palmar surfaces of the hands and fingers, and upon the plantar surfaces of the feet and toes, they are large, closely aggregated together, and arranged in parallel curved lines, forming the elevated ridges seen on the free surface of the epidermis. Each ridge contains two rows of papillæ, and between the rows the ducts of the sudoriferous glands pass outwards to open on the summit of the ridge. Each papilla consists of very small and closely interlacing bundles of finely fibrillated tissue, with a few elastic fibres; within this tissue is a capillary loop, and in some papillæ, especially in the palms of the hands and the fingers, there are tactile corpuscles.

The *arteries* supplying the skin form a network in the subcutaneous tissue, and from this network branches are distributed to the sudoriferous glands, the hair-follicles, and the fat. Other branches unite in a plexus immediately beneath the corium; from this plexus, fine capillary vessels pass into the papillæ, forming

FIG. 934.—A longitudinal section through the root of a nail.



a single capillary loop in the smaller papillæ, but in the larger ones dividing into two or more capillary vessels. The *lymphatic vessels* of the skin form a superficial and a deep network, which communicate with each other and with the lymphatic vessels of the subcutaneous tissue by oblique branches.

The *nerves* of the skin terminate partly in the epidermis and partly in the corium; their different modes of ending are described on pp. 1005 to 1007.

The **appendages of the skin** are the nails, the hairs, and the sudoriferous and sebaceous glands with their ducts.

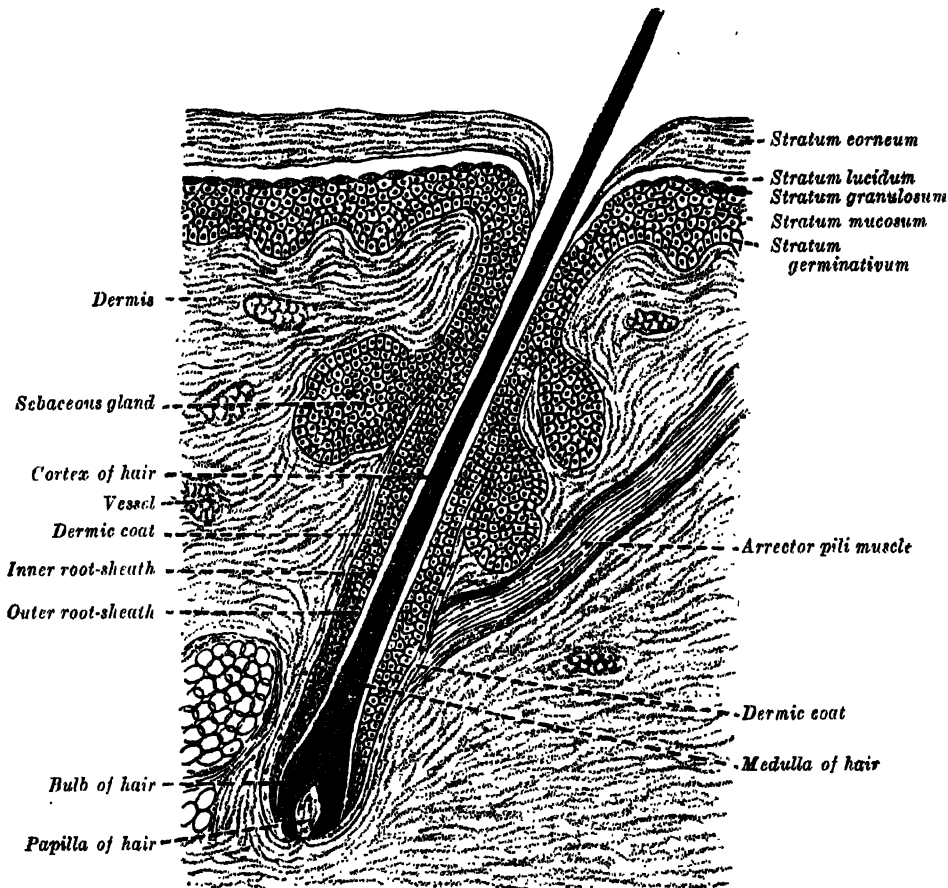
The **nails** (fig. 934) are flattened, elastic structures of a horny texture, placed upon the distal parts of the dorsal surfaces of the terminal phalanges of the fingers and toes. Each is implanted into a groove in the skin by a portion called the *root*; the exposed part is called the *body*, and the distal extremity the *free edge*. The nail is firmly adherent to the corium, being accurately moulded upon its surface; the part of the corium beneath the body and root of the nail is called the *nail-matrix*, because from it the nail is produced. Under the greater part of the body of the nail the matrix is thick, and raised into a series of longitudinal ridges which are very vascular, and the colour is seen through the transparent tissue. Near the root of the nail the papillæ are smaller, less vascular, and have no regular arrangement, and here the tissue of the nail is more opaque; hence this portion is of a white colour, and is called the *lunula* on account of its shape.

As the cuticle passes forwards on the dorsal surface of the finger or toe it is attached to the surface of the nail a little in advance of its root; at the extremity of the finger it is connected with the under surface of the nail a little behind its free edge. The cuticle and the horny substance of the nail (both epidermic structures) are thus directly continuous with each other. The superficial, horny part of the nail consists of a greatly thickened stratum lucidum, the stratum corneum forming merely the thin cuticular fold (*eponychium*) which overlaps the lunula;

the deeper part consists of the stratum mucosum. The cells in contact with the papillæ of the matrix are columnar in form and arranged perpendicularly to the surface; those which succeed them are rounded or polygonal, while the more superficial ones are thin and flat, and so closely packed as to make the limits of the cells very indistinct. The nails grow in length by the proliferation of the cells of the stratum mucosum at the root of the nail, and in thickness from that part of the stratum mucosum which underlies the lunula.

Hairs are found on nearly every part of the surface of the body, but are absent from the palms of the hands, the soles of the feet, the dorsal surfaces of the terminal

FIG. 935.—A section of the skin, showing the epidermis and dermis, a hair in its follicle, the Arrector pili muscle, with sebaceous glands opening into the hair-follicle.



phalanges, the glans penis, the inner surface of the prepuce, and the inner surfaces of the labia. They vary much in length, thickness, and colour in different parts of the body and in different races of mankind. In some parts, as in the skin of the eyelids, they are so short as not to project beyond the follicles containing them; in others, as upon the scalp, they are of considerable length; the eyelashes, the hairs of the pubic region, and the whiskers and beard are remarkable for their thickness. Straight hairs are stronger than curly hairs and present on transverse section a cylindrical or oval outline: curly hairs, on the other hand, are flat.

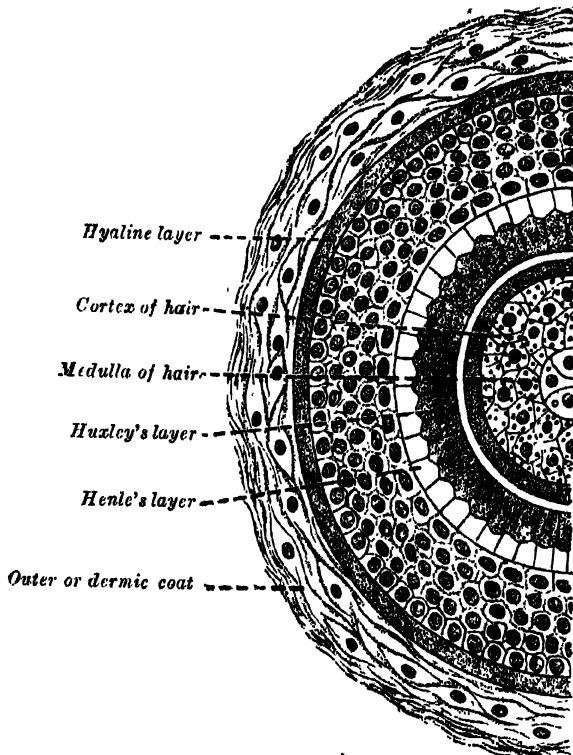
A hair consists of a *root*, the part implanted in the skin; and a *shaft* or *scapus*, the portion projecting from the surface.

The *root of the hair* ends in an enlargement, the *hair-bulb*, which is whiter in colour and softer in texture than the shaft, and is lodged in an involution of the epidermis and superficial portion of the dermis, called the *hair-follicle* (fig. 935). When the hair is of considerable length the follicle extends into the subcutaneous

tissue. The hair-follicle commences on the surface of the skin with a funnel-shaped opening, and passes inwards in an oblique or curved direction—the latter in curly hairs—to become dilated at its deep extremity, where it corresponds with the hair-bulb. Opening into the follicle, near its free extremity, are the ducts of one or more sebaceous glands. At the bottom of each hair-follicle is a small conical, vascular eminence or papilla, similar in every respect to those found upon the surface of the skin; it is continuous with the dermic layer of the follicle, and is supplied with nerve-fibrils. The hair-follicle consists of two coats—an outer or *dermic*, and an inner or *epidermic*.

The *outer* or *dermic* coat is formed mainly of fibrous tissue; it is continuous with the corium, is highly vascular, and supplied by numerous minute nervous filaments. It consists of three layers (fig. 936). The most internal is a hyaline

FIG. 936.—A transverse section of a hair-follicle.



basement membrane, which is well marked in the larger hair-follicles, but is not very distinct in the follicles of minute hairs; it is limited to the deeper part of the follicle. Outside this is a compact layer of fibres and spindle-shaped cells arranged circularly around the follicle; this layer extends from the bottom of the follicle to the openings of the ducts of the sebaceous glands. Externally is a thick layer of connective tissue, arranged in longitudinal bundles, forming a more open texture and corresponding with the reticular part of the corium; in this are contained the blood-vessels and nerves.

The *inner* or *epidermic* coat is closely adherent to the root of the hair, and consists of two strata named respectively the *outer* and *inner root-sheaths*; the outer root-sheath corresponds with the stratum mucosum of the epidermis, and resembles it in the rounded form and soft character of its cells; at the bottom of the hair-follicle these cells become continuous with those of the root of the hair. The inner root-sheath consists of: (1) a delicate cuticle next the hair, composed of a single layer of imbricated scales with atrophied nuclei; (2) one or two layers of horny, flattened, nucleated cells, known as *Huxley's layer*; and (3) a single layer of cubical cells with clear flattened nuclei, called *Henle's layer*.

The *hair-bulb* is moulded over the papilla and composed of polyhedral epithelial cells, which as they pass upwards into the root of the hair become elongated and spindle-shaped, except those in the centre, which remain polyhedral.

The *shaft of the hair* consists, from within outwards, of the medulla, the cortex, and the cuticle. The *medulla* is usually absent from the fine hairs covering the surface of the body, and commonly from those of the head. When viewed by transmitted light it appears deeper in colour and more opaque than the cortex, but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, with air-spaces between, and sometimes within, the cells. The *cortex* constitutes the chief part of the shaft; its cells are elongated and are united to form flattened fusiform fibres which contain pigment-granules in dark hair, and air in white hair. The *cuticle* consists of a single layer of flat scales which overlap one another from below upwards.

Connected with the hair-follicles are minute bundles of involuntary muscular fibres, termed the *Arrectores pilorum* (fig. 935). They arise from the superficial layer of the corium, and are inserted into the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side towards which the hair slopes, and by their action diminish the obliquity of the follicle and elevate the hair.* The sebaceous gland is situated in the angle which the arrector muscle forms with the superficial portion of the hair-follicle, and contraction of the muscle thus tends to squeeze the sebaceous secretion out from the duct of the gland.

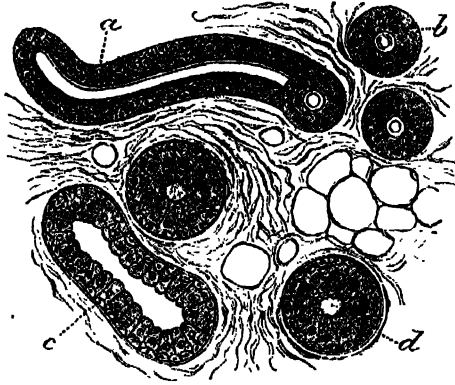
The **sebaceous glands** (fig. 935) are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, but are especially abundant in the scalp and face; they are also very numerous around the apertures of the anus, nose, mouth, and external ear, but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which emerges from a cluster of oval or flask-shaped alveoli, usually from two to five, but in some instances as many as twenty in number. Each alveolus is composed of a transparent basement membrane, enclosing a number of epithelial cells. The outer or marginal cells are small and polyhedral, and are continuous with the cells lining the duct. The remainder of the alveolus is filled with larger cells, containing fat, except in the centre, where the cells are broken up, leaving a cavity filled with their debris and a mass of fatty matter, which constitutes the *sebum cutaneum*. The ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margins of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The tarsal glands of the eyelids are elongated sebaceous glands with numerous lateral diverticula.

The **sudoriferous or sweat glands** are found in almost every part of the skin, and are situated in small pits on the under surface of the corium, or, more frequently, in the subcutaneous tissue, surrounded by a quantity of adipose tissue. Each consists of a single tube, the deep part of which is rolled into an oval or spherical ball, named the *body* of the gland, while the superficial part, or *duct*, traverses the corium and cuticle and opens on the surface of the skin by a funnel-shaped aperture. In the superficial layers of the corium the duct is straight, but in the deeper layers it is convoluted or twisted; where the epidermis is thick, as in the palms of the hands and soles of the feet, the part of the duct which passes through it is spirally coiled. The size of the glands varies. They are especially large in those regions where the amount of perspiration is great, as in the axillæ, where they form a thin, manillated layer of a reddish colour, which corresponds exactly with the situation of the hair in this region; they are large also in the groin. Their number varies. They are very plentiful on the palms of the hands, and on the soles of the feet, where the orifices of the ducts are exceedingly regular, and open on the curved ridges; they are least numerous in the neck and back. The tube, both in the body of the gland and in the duct, consists of two layers—an outer, of fine areolar tissue, and an inner of epithelium (fig. 937). The outer layer is thin and is continuous with the superficial stratum of the corium. In the body

* Professor Arthur Thomson of Oxford suggests that the contraction of these muscles on follicles which contain weak, flat hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.

of the gland the epithelium consists of a single layer of cubical cells, between the deep ends of which and the basement membrane is a layer of longitudinally or obliquely arranged non-striped muscular fibres. The ducts are destitute of muscular fibres and are composed of a basement membrane lined by two or three layers of

FIG. 937.—The body of a sudoriferous gland cut in various directions. (From Klein and Noble Smith's Atlas of Histology.)



a. Longitudinal section of the proximal part of the coiled tube. *b.* Transverse section of the same. *c.* Longitudinal section of the distal part of the coiled tube. *d.* Transverse section of the same.

polyhedral cells; the lumen of the duct is coated by a thin cuticle. When the epidermis is carefully removed from the surface of the corium, the ducts may be drawn out in the form of short, thread-like processes on its under surface. The ceruminous glands of the external acoustic meatus are modified sudoriferous glands.

SPLANCHNOLOGY

UNDER this heading are described the respiratory, digestive, and urogenital organs, and the ductless glands.

RESPIRATORY APPARATUS

The respiratory apparatus consists of the larynx, trachea, bronchi, lungs, and pleuræ.

THE LARYNX

The larynx, the organ of the voice, is placed at the upper part of the air-passage. It is situated between the trachea and the root of the tongue, at the upper and anterior part of the neck, where it presents a considerable projection. It forms the lower part of the anterior wall of the pharynx, and is covered behind by the mucous lining of that cavity; on either side of it lie the great vessels of the neck. In the adult male it is situated opposite the fourth, fifth, and sixth cervical vertebræ, but is placed somewhat higher in the female and also during childhood. Symington states that in infants of between six and twelve months of age the tip of the epiglottis is a little above the level of the fibrocartilage between the dens and body of the epistropheus, and that from infancy to adult life the larynx descends for a distance equal to two vertebral bodies and two intervertebral fibrocartilages. The average measurements of the adult larynx are as follows:

	In males.	In females.
Length	44 mm.	36 mm.
Transverse diameter	43 "	41 "
Anteroposterior diameter	36 "	26 "
Circumference	136 "	112 "

Until puberty the larynx of the male differs little in size from that of the female. In the female its increase at puberty is only slight. In the male its increase is considerable; all the cartilages enlarge and the thyroid cartilage projects in the middle line of the neck, while the length of the rima glottidis is nearly doubled.

The larynx is broad above, where it presents the form of a prismatic box, flattened behind and at the sides, and bounded in front by a prominent vertical ridge. Below, it is narrow and cylindrical. It is composed of cartilages, which are connected by ligaments and moved by numerous muscles. It is lined by mucous membrane continuous above and behind with that of the pharynx and below with that of the trachea.

The cartilages of the larynx (fig. 938) are nine in number, three single and three paired, as follows:

Thyroid.	Two Corniculate.
Cricoid.	Two Cuneiform.
Two Arytænoid.	Epiglottis.

The thyroid cartilage is the largest cartilage of the larynx. It consists of two laminae, the anterior borders of which are joined with each other at an angle in the middle line of the neck, and form a subcutaneous projection

named the *laryngeal prominence* (pomum Adami). This prominence is most distinct at its upper part, and is larger in the male than in the female. Immediately above it the laminae are separated by a V-shaped notch, the *superior thyroid notch*.

The *laminae* are irregularly quadrilateral in shape, and their posterior angles are prolonged into processes termed the *superior* and *inferior cornua*. On the *outer surface* of each lamina an *oblique line* runs downwards and forwards from the superior thyroid tubercle situated near the root of the superior cornu, to the inferior thyroid tubercle on the lower border. This line gives attachment to the Sternothyroideus, Thyrohyoideus, and Constrictor pharyngis inferior.

The *inner surface* is smooth: above and behind, it is slightly concave and covered by mucous membrane. In front, in the angle formed by the junction of the laminae, are attached the stem of the epiglottis, the ventricular and vocal ligaments, the Thyrocartyloidei, Thyroepiglottici and Vocales muscles, and the thyroepiglottic ligament.

The *upper border* is concave behind and convex in front; it gives attachment to the corresponding half of the hyothyroid membrane.

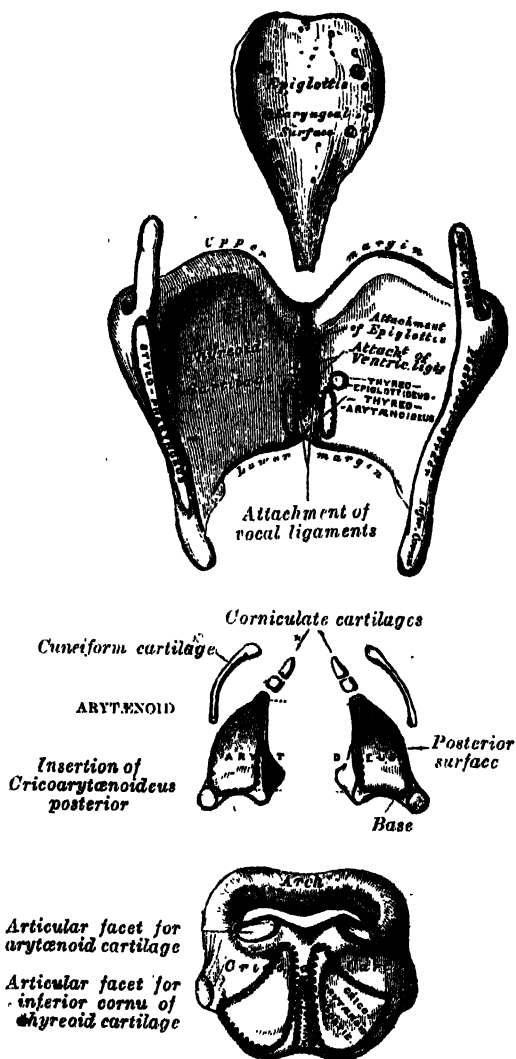
The *lower border* is concave behind, and nearly straight in front, the two parts being separated by the inferior thyroid tubercle. A small part of it in and near the middle line is connected to the cricoid cartilage by the middle cricothyroid ligament.

The *posterior border*, thick and rounded, receives the insertions of fibres of the Stylopharyngeus and Pharyngopalatinus muscles. It ends in the superior and inferior cornua. The *superior cornu* is long and narrow, directed upwards, backwards, and medialwards, and ends in a conical extremity, which gives attachment to the lateral hyothyroid ligament. The *inferior cornu* is short and thick: it is directed downwards, with a slight inclination forwards and medialwards, and has, on the medial side of its tip, a small oval facet for articulation with the side of the cricoid cartilage.

The *anterior border* is fused with that of the opposite lamina, forming with it an angle of about 90° in the adult male, and about 120° in the adult female.

During infancy the laminae of the thyroid cartilage are joined to each other by a narrow, lozenge-shaped strip, named the *intrathyroid cartilage*, which extends from the upper to the lower border of the cartilage in the middle line, and is distinguished from the laminae by being more flexible and transparent.

FIG. 988.—The cartilages of the larynx.
Posterior view.



The **cricoid cartilage** is smaller, but thicker and stronger than the thyroid, and forms the lower and posterior parts of the wall of the larynx. It consists of (a) a posterior quadrate lamina, and (b) a narrow anterior arch.

The *lamina* is deep and broad, and measures vertically from 2 cm. to 3 cm.; on the middle of its posterior surface is a vertical ridge to the upper part of which the two fasciculi of the longitudinal fibres of the œsophagus are attached by a stout tendon (p. 1081); and on either side of the ridge is a broad depression for the origin of the *Cricarytænoides posterior*.

The *arch* is narrow and convex, and measures vertically from 5 mm. to 7 mm.; it affords attachment in front and at the sides to the *Cricothyreoides*, and behind, to part of the *Constrictor pharyngis inferior*.

On either side, at the junction of the lamina with the arch, is a small round facet, directed lateralwards and backwards, for articulation with the inferior cornu of the thyroid cartilage.

The *lower border* of the cricoid cartilage is horizontal, and connected to the highest ring of the trachea by the cricotracheal ligament. The *upper border* runs obliquely upwards and backwards, owing to the great depth of the lamina. It gives attachment, in front, to the middle cricothyroid ligament; at the sides, to the conus of the *Cricarytænoides laterales*; behind, it presents, in the middle, a shallow notch, and on either side of this is a smooth, oval, convex surface, directed upwards and lateralwards, for articulation with the base of an arytenoid cartilage.

The *inner surface* of the cricoid cartilage is smooth, and lined by mucous membrane.

The **arytænoid cartilages** two in number, are situated at the upper border of the lamina of the cricoid cartilage, at the back of the larynx. Each is pyramidal in form, and has three surfaces, a base, and an apex.

The *posterior surface* is triangular, smooth, concave, and gives attachment to the *Arytænoides obliquus* and *transversus*.

The *anterolateral surface* is somewhat convex and rough. On it, near the apex of the cartilage, is a rounded elevation (*colliculus*) from which a crest (*crista arcuata*) curves: at first backwards and then downwards and forwards to the vocal process. The lower part of this crest intervenes between two depressions or foveæ, an upper, triangular, and a lower, oblong in shape; to the upper the ventricular ligament is attached; to the lower, the *Vocalis* and *Cricarytænoides lateralis*.

The *medial surface* is narrow, smooth, and flat; it is covered by mucous membrane, and forms the lateral boundary of the intercartilaginous part of the rima glottidis.

The *base* of each cartilage is convex, and on it is a smooth surface for articulation with the cricoid cartilage. Its lateral angle or *muscular process*, short, rounded, and prominent, projects backwards and lateralwards, and gives insertion to the *Cricarytænoides posterior* behind, and to the *Cricarytænoides lateralis* in front. Its anterior angle or *vocal process* is prominent and pointed; it projects horizontally forwards and gives attachment to the vocal ligaments.

The *apex* of each cartilage curves backwards and medialwards, and is surmounted by the *corniculate cartilage*.

The **corniculate cartilages** (cartilages of Santorini) are two small conical nodules consisting of yellow elastic cartilage, which articulate with the summits of the arytenoid cartilages and serve to prolong them backwards and medialwards. They are situated in the posterior parts of the aryepiglottic folds of mucous membrane, and are sometimes fused with the arytenoid cartilages.

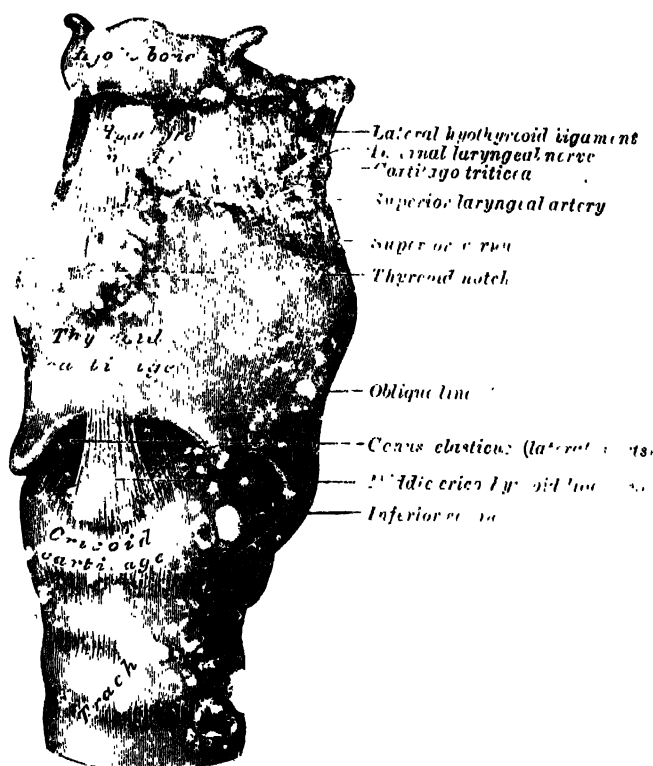
The **cuneiform cartilages** (cartilages of Wrisberg) are two small, elongated pieces of yellow elastic cartilage, placed one on either side, in the aryepiglottic fold, where they give rise to small whitish elevations on the surface of the mucous membrane, just in front of the corniculate cartilages.

The **epiglottis** is a thin lamella of yellow fibrocartilage, shaped like a leaf, and projecting obliquely upwards and forwards behind the root of the tongue, in front of the entrance to the larynx. The free extremity is broad and rounded; the attached part or stem is long, narrow, and connected by an elastic ligament, the *thyreo-epiglottic ligament*, to the angle formed by the two laminae of the thyroid cartilage, a short distance below the superior thyroid

notch. The lower part of its anterior surface is connected to the upper border of the body of the hyoid bone by an elastic filamentous band, the *hyo-epiglottic ligament*.

The *anterior or lingual surface* is covered on its upper, free part by mucous membrane which is reflected on to the sides and root of the tongue, forming a median and two lateral *glosso-epiglottic folds*; the lateral glosso-epiglottic folds are partly attached to the wall of the pharynx. The depressions between the epiglottis and the root of the tongue, on either side of the median fold, are named the *valleculæ* (fig. 942). The lower part of this surface lies behind the hyoid bone, the thyrohyoid membrane, and the upper part of the thyroid cartilage, but is separated from these structures by a mass of fatty tissue.

FIG. 939.—The ligaments of the larynx. Anteroposterior view.



The *posterior or laryngeal surface* is smooth, concave from side to side, concavoconvex from above downwards; its lower part projects backwards as an elevation, the *tubercle or cushion*. When the mucous membrane is removed, the surface of the cartilage is seen to be indented by a number of small pits, in which mucous glands are lodged. The aryepiglottic folds are attached to the sides of the epiglottis.

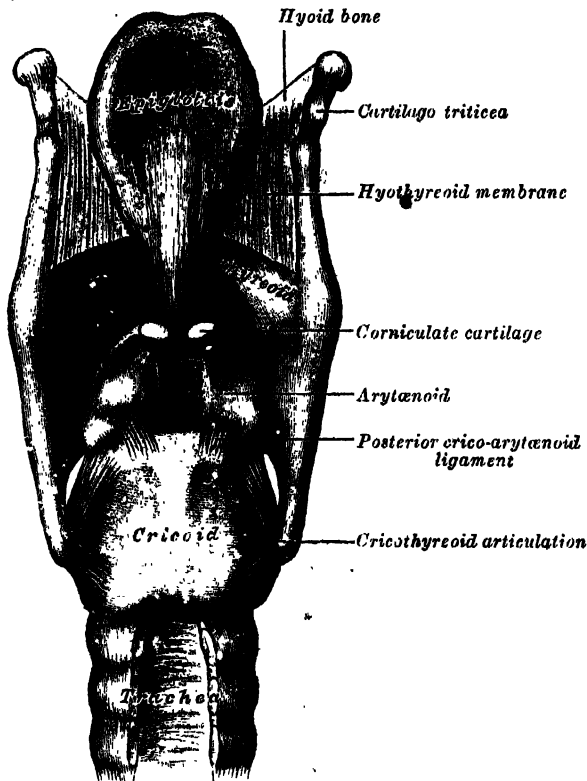
Structure.—The corniculate and cuneiform cartilages, the epiglottis, and the apices of the arytenoids at first consist of hyaline cartilage, but later, elastic fibres are deposited in the matrix, converting them into yellow fibrocartilage, which shows little tendency to calcification. The thyroid, cricoid, and the greater part of the arytenoids consist of hyaline cartilage, and become more or less ossified as age advances. Ossification commences about the twenty-fifth year in the thyroid cartilage, and somewhat later in the cricoid and the arytenoids; by the sixty-fifth year these cartilages may be completely converted into bone.

Ligaments.—The ligaments of the larynx (figs. 939, 940) are (a) *extrinsic*, those connecting the thyroid cartilage and epiglottis with the hyoid bone, and the cricoid cartilage with the trachea; and (b) *intrinsic*, those uniting the cartilages of the larynx to each other.

Extrinsic ligaments.—The thyroid cartilage is connected to the hyoid bone by the hyothyroid membrane, and by a middle and two lateral hyothyroid ligaments.

The *hyothyroid membrane* is a broad, fibro-elastic layer, attached below to the upper border of the thyroid cartilage and to the front of its superior cornu, and above to the upper margin of the posterior surface of the body and greater cornu of the hyoid bone, thus passing behind the posterior surface of the body of the hyoid bone, and being separated from it by a bursa mucosa, which facilitates the upward movement of the larynx during deglutition. The middle, thicker, part of the membrane is termed the *middle hyothyroid*

FIG. 940.—The ligaments of the larynx. Posterior view.



ligament; each of its lateral thinner portions is pierced by the superior laryngeal vessels and the internal branch of the superior laryngeal nerve. Its anterior surface is in relation with the Thyrohyoideus, Sternohyoideus, and Omohyoideus, and with the body of the hyoid bone.

The *lateral hyothyroid ligaments* are round elastic cords which form the posterior borders of the hyothyroid membrane and pass between the tips of the superior cornua of the thyroid cartilage and the extremities of the greater cornua of the hyoid bone. A small cartilaginous nodule, the *cartilago triticea*, is frequently found in each ligament.

An elastic band, the *hyo-epiglottic ligament*, connects the anterior surface of the epiglottis to the upper border of the body of the hyoid bone.

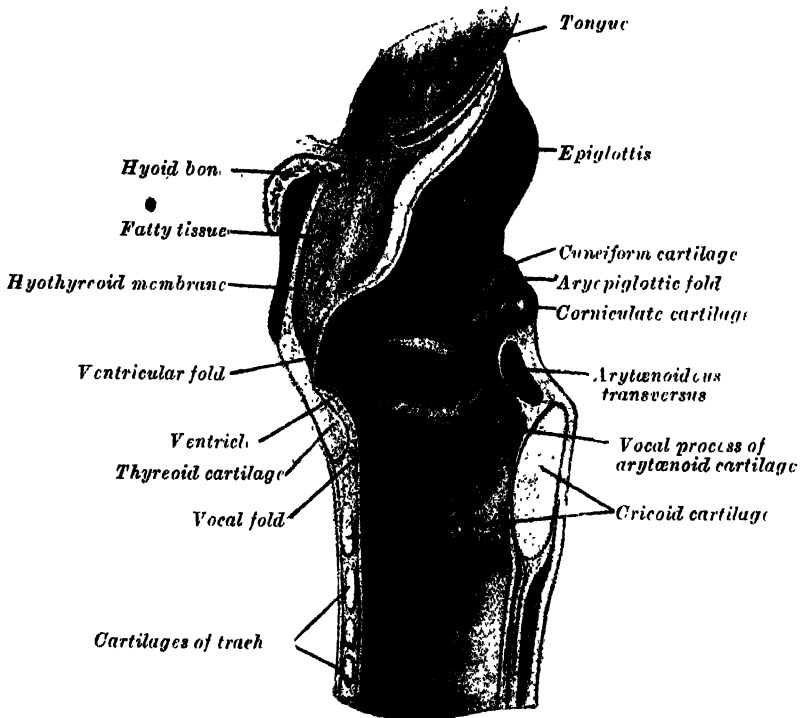
The *cricotracheal ligament* unites the lower border of the cricoid cartilage with the first ring of the trachea. It is continuous below with the fibrous membrane which unites the rings of the trachea to each other.

Intrinsic ligaments.—Beneath the mucous membrane of the larynx is a broad sheet of fibrous tissue containing many elastic fibres, and termed the *elastic membrane of the larynx*. It is subdivided on either side by the interval

between the ventricular and vocal ligaments; the upper portion extends between the arytenoid cartilage and the epiglottis, and is often poorly defined; the lower part is a well-marked membrane forming, with its fellow of the opposite side, the conus elasticus, which connects the thyroid, cricoid, and arytenoid cartilages one to another. The joints between the individual cartilages are also provided with ligaments.

The *conus elasticus* (cricothyroid membrane) is composed mainly of yellow elastic tissue. It consists of an anterior and two lateral portions. The *anterior* part or *middle cricothyroid ligament* is thick and strong, narrow above and broad below. It connects together the front parts of the contiguous margins

FIG. 941.—A sagittal section of the larynx.



of the thyroid and cricoid cartilages. It is overlapped on either side by the Cricothyroideus, but between these muscles it is subcutaneous; it is crossed horizontally by a small arterial arch, formed by the junction of the two cricothyroid arteries; branches of this arch pierce the ligament. The *lateral* portions of the conus elasticus are thinner; they are lined by the mucous membrane of the larynx and covered by the Cricoarytaenoidei laterales and Thyroarytaenoidei. They extend from the inner edge of the superior border of the cricoid cartilage to the inferior margins of the vocal ligaments, with which they are continuous. These ligaments may therefore be regarded as the free borders of the lateral portions of the conus elasticus; they stretch from the vocal processes of the arytenoid cartilages to the angle of the thyroid cartilage about midway between its upper and lower borders.

An *articular capsule*, strengthened posteriorly by a well-marked fibrous band, encloses the arthrodial joint between the inferior cornu of the thyroid and the cricoid cartilage.

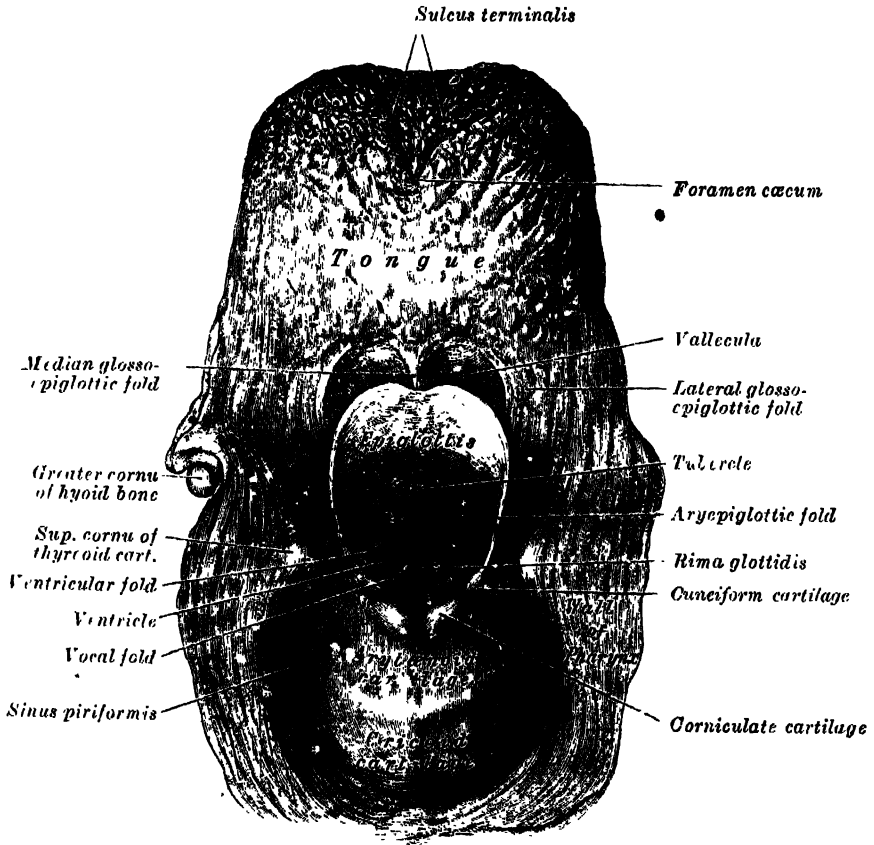
Each arytenoid cartilage is connected to the cricoid by an articular capsule and a posterior cricoarytenoid ligament. The *articular capsule* is thin and loose, and is attached to the margins of the articular surfaces. The *posterior crico-arytenoid ligament* extends from the cricoid to the medial and posterior part of the base of the arytenoid.

The *thyreo-epiglottic ligament* is a long, slender, elastic cord which connects the stem of the epiglottis to the angle of the thyroid cartilage below the superior thyroid notch and above the attachment of the ventricular ligaments.

Movements.—The articulations between the inferior cornua of the thyroid cartilage and the cricoid cartilage are diarthrodial, and permit of rotatory and gliding movements. The rotatory movement is one in which the cricoid cartilage rotates upon the inferior cornua of the thyroid cartilage around an axis passing transversely through both joints. The gliding movement consists in a limited shifting of the cricoid on the thyroid in different directions.

The articulations between the arytenoid cartilages and the cricoid cartilage are also diarthrodial, and permit of two varieties of movement: one is a rotation

FIG. 942.—The tongue and the entrance to the larynx, viewed from behind.



of the arytenoid on a vertical axis, whereby the vocal process is moved lateralwards or medialwards, and the rima glottidis increased or diminished; the other is a gliding movement, and allows the arytenoid cartilages to approach or recede from each other: from the direction and slope of the articular surfaces lateral gliding is accompanied by a forward and downward movement. The two movements of gliding and rotation are associated, the medial gliding being connected with medialward rotation, and the lateral gliding with lateralward rotation. The posterior crico-arytenoid ligaments limit the forward movements of the arytenoid cartilages on the cricoid.

Cavum laryngis (figs. 941, 942).—The cavity of the larynx extends from the laryngeal entrance to the lower border of the cricoid cartilage, where it is continuous with the tube of the trachea. It is divided into two parts by the medial projection of the vocal folds, between which is a narrow triangular fissure or chink, the *rima glottidis*. The portion of the cavity above the vocal folds is called the *vestibule*; it is wide above and narrow below; near the centre of its anterior wall is the low backward projection of the tubercle or

cushion of the epiglottis. The ventricular folds project into the lower part of the vestibule, and between them and the vocal folds are the *ventricles* of the larynx. The portion below the vocal folds is elliptical above, but lower down it widens, assumes a circular form, and is continuous with the tube of the trachea.

The *entrance to the larynx* (aditus laryngis) (fig. 942) is triangular, wide in front, narrow behind, and slopes obliquely downwards and backwards. It is bounded, in front, by the epiglottis; behind, by the apices of the arytaenoid cartilages, the corniculate cartilages, and the interarytaenoid notch; and on either side, by a fold of mucous membrane, enclosing ligamentous and muscular fibres, stretched between the side of the epiglottis and the apex of the arytaenoid cartilage; this is the *aryepiglottic fold*, on the posterior part of the margin of which the cuneiform cartilage forms a more or less distinct whitish prominence, the *cuneiform tubercle*.

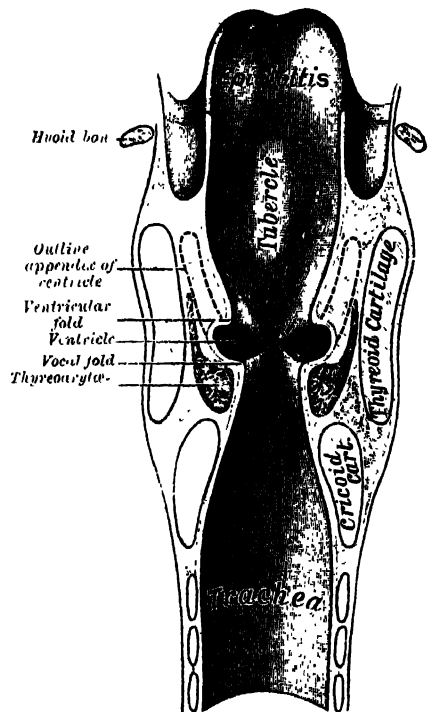
The *ventricular folds* (false vocal cords) are two thick folds of mucous membrane, each enclosing a narrow band of fibrous tissue, the *ventricular ligament*, which is fixed in front to the angle of the thyroid cartilage immediately below the attachment of the epiglottis, and behind to the anterolateral surface of the arytaenoid cartilage, a short distance above the vocal process. The lower border of this ligament, enclosed in thick mucous membrane, forms a free crescentic margin, which constitutes the upper boundary of the ventricle of the larynx.

The *vocal folds* (true vocal cords) are concerned in the production of sound, and enclose two strong bands, named the *vocal ligaments*. Each ligament consists of a band of yellow elastic tissue, attached in front to the angle of the thyroid cartilage below the ventricular ligament, and behind to the vocal process of the arytaenoid. Its lower border is continuous with the lateral part of the conus elasticus. Its upper border forms the lower boundary of the ventricle of the larynx. Laterally, the Vocalis muscle lies parallel with it. It is covered medially by mucous membrane, which is extremely thin, and closely adherent to it.

The *ventricle of the larynx* is a fusiform fossa on either side, between the ventricular and vocal folds and extending nearly their entire length. The fossa is bounded above, by the free edge of the ventricular fold; below, by the margin of the vocal fold; laterally, by the mucous membrane covering the corresponding Thyreoarytaenoideus. The anterior part of the ventricle leads up by a narrow opening into a pouch of mucous membrane of variable size, called the *appendix*.

The *appendix of the ventricle* (laryngeal saccule) is a membranous sac, placed between the ventricular fold and the inner surface of the thyroid cartilage, occasionally extending as far as the upper border of the cartilage, or even higher; it is conical in form, and curved slightly backwards. On the surface of its mucous membrane are the openings of sixty or seventy mucous glands, which are lodged in the submucous areolar tissue. This sac is enclosed in a fibrous capsule, continuous below with the ventricular ligament. Its medial surface is covered by a few delicate muscular fasciculi, which arise from the apex of the arytaenoid cartilage and become lost in the aryepiglottic fold of mucous membrane; laterally it is separated from the thyroid cartilage by

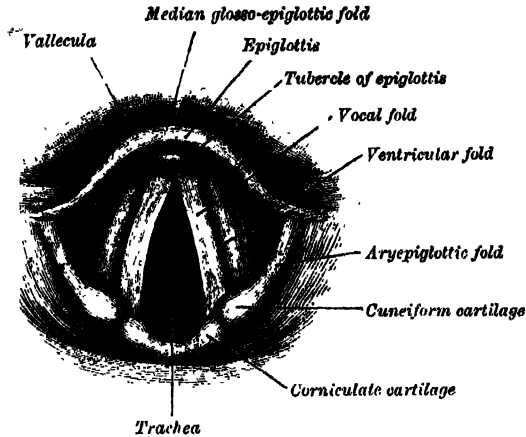
FIG. 943.—A coronal section of the larynx and the upper part of the trachea.



the Thyreoepiglotticus. These muscles compress the sac, and express the secretion it contains upon the vocal fold to lubricate its surfaces.

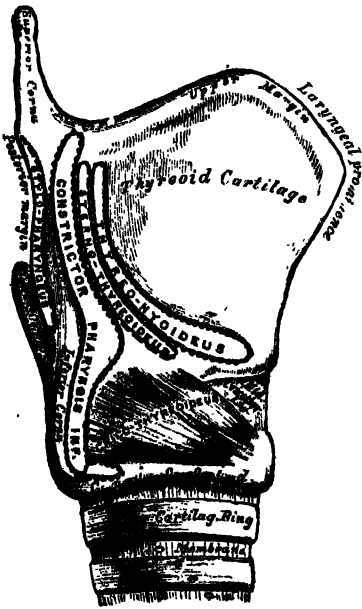
The *rima glottidis* (fig. 942) is the fissure bounded on either side by the vocal folds in front, and the bases and vocal processes of the arytaenoid cartilages

FIG. 944.—A laryngoscopic view of the interior of the larynx.



behind. It is therefore subdivided into an anterior intermembranous part (glottis vocalis), which measures about three-fifths of the length of the entire aperture, and a posterior intercartilaginous part (glottis respiratoria). Posteriorly it is limited by the mucous membrane passing between the arytaenoid cartilages. The rima glottidis is the narrowest part of the cavity of the larynx, and its level corresponds with the bases of the arytaenoid cartilages. Its length, in the male, is about 23 mm.; in the female from 17 mm. to 18 mm. The width and shape of the rima glottidis vary with the movements of the vocal folds and arytaenoid cartilages during respiration and phonation. In the condition of rest, i.e. when these structures are uninfluenced by muscular action, as in quiet respiration, the intermembranous part is triangular, with its apex in front and its base behind—the latter being represented by a line, about 8 mm. long, connecting the anterior ends of the vocal processes—while the medial surfaces of the arytaenoids are parallel to each other and hence the intercartilaginous part is rectangular. During extreme adduction of the vocal folds, as in the emission of a high note, the intermembranous part of the rima glottidis is reduced to a linear slit by the apposition of the vocal folds; while the intercartilaginous part is triangular, its apex corresponding to the anterior ends of the vocal processes of the arytaenoids, which are approximated by the medial rotation of the cartilages. Conversely in extreme abduction of the vocal folds, as in forced inspiration, the arytaenoids and

FIG. 945.—A side view of the larynx showing the muscular attachments.



their vocal processes are rotated lateralwards, and the intercartilaginous part is triangular in shape but with its apex directed backwards. In this condition the rima glottidis is somewhat lozenge-shaped, the sides of the intermembranous part diverging from before backwards, those of the intercartilaginous part

diverging from behind forwards—the widest part of the aperture corresponding with the attachments of the vocal folds to the vocal processes.

Muscles.—The muscles of the larynx are *extrinsic* and *intrinsic*. The former pass between the larynx and neighbouring structures, and are described in the section on Myology; the latter are confined to the larynx.

The intrinsic muscles are:

Cricothyreoides,
pars obliqua,
pars recta.

Cricoarytænoides posterior.

Cricoarytænoides lateralis.

Arytænoides transversus.

Arytænoides obliquus.

Aryepiglotticus.

Thyrecoarytænoides (externus).

Vocalis.

Thyreopiglotticus.

Ventricularis.

With the exception of the Arytænoides transversus all these muscles are paired.

FIG. 946.—The muscles of the larynx. Posterior view.

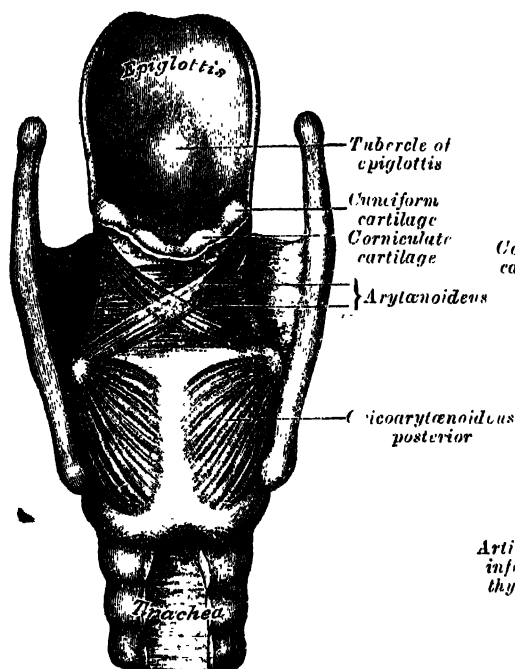
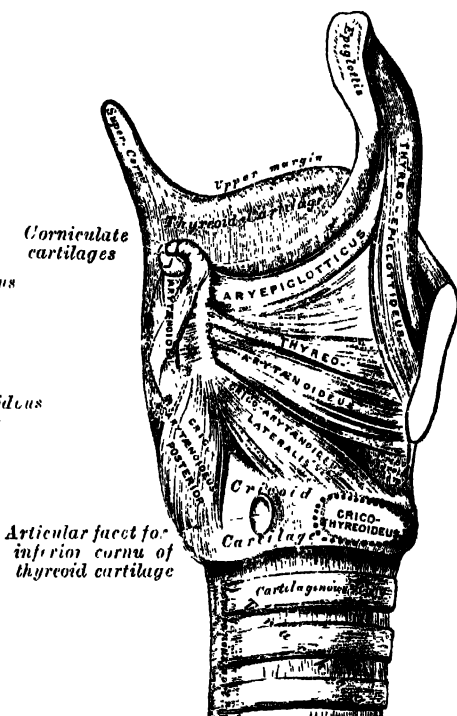


FIG. 947.—The muscles of the larynx. Side view. The right lamina of the thyroid cartilage has been removed.



The *Cricothyreoides* (fig. 945), triangular in form, arises from the front and lateral part of the outer surface of the cricoid cartilage; its fibres diverge, and are arranged in two groups. The lower fibres constitute the *pars obliqua*, and slant backwards and lateralwards to the anterior border of the inferior cornu; the anterior fibres form the *pars recta* and run upwards and backwards to the posterior part of the lower border of the lamina of the thyroid cartilage.

The medial borders of the two muscles are separated by a triangular interval occupied by the subcutaneous part of the middle cricothyroid ligament.

The *Cricoarytænoides posterior* (fig. 946) arises from the broad depression on the corresponding half of the posterior surface of the lamina of the cricoid cartilage; its fibres, directed upwards and lateralwards, converge to be inserted into the back of the muscular process of the arytaenoid cartilage. The highest fibres are nearly horizontal, the middle oblique, and the lowest almost vertical.

The *Cricoarytænoides lateralis* (fig. 947) is smaller than the preceding and

of an oblong form. It arises from the upper border of the arch of the cricoid cartilage, and, passing obliquely upwards and backwards, is inserted into the front of the muscular process of the arytenoid cartilage.

The *Arytænoideus transversus* (fig. 946) is a single muscle, filling up the posterior concave surfaces of the arytenoid cartilages. It arises from the posterior surface and lateral border of the arytenoid cartilage of one side, and is inserted into the corresponding parts of the cartilage on the opposite side.

The *Arytænoideus obliquus*, superficial to the *Arytænoideus transversus*, consists of two fasciculi, which cross each other like the limbs of the letter X. Each passes from the base of one arytenoid cartilage to the apex of the other. A few fibres are continued round the lateral margin of the cartilage, and are prolonged into the aryepiglottic fold; they constitute the *Aryepiglotticus* muscle.

The *Thyroarytænoideus* (figs. 947, 948) is a broad, thin muscle, which lies laterally to the vocal fold, the conus elasticus, the ventricle and the ventricular appendix. It arises in front from the lower half of the angle of the thyroid cartilage, and from the middle cricothyroid ligament. Its fibres pass backwards and lateralwards, to be inserted into the base and anterior surface of the arytenoid cartilage. The lower and deeper fibres of the muscle form a triangular band which is inserted into the vocal process of the arytenoid cartilage, and into the adjacent portion of its anterior surface; it is termed the *Vocalis*, and lies parallel with the vocal ligament, to which it is adherent. A considerable number of the fibres of the *Thyroarytænoideus* are prolonged into the aryepiglottic fold, where some of them are lost, while others are continued to the margin of the epiglottis, forming the *Thyroepiglotticus*; the *Thyroepiglottici*, together with the *Aryepiglottici*, are sometimes described as the *Sphincter glottidis*. A few fibres extend along the wall of the ventricle from the

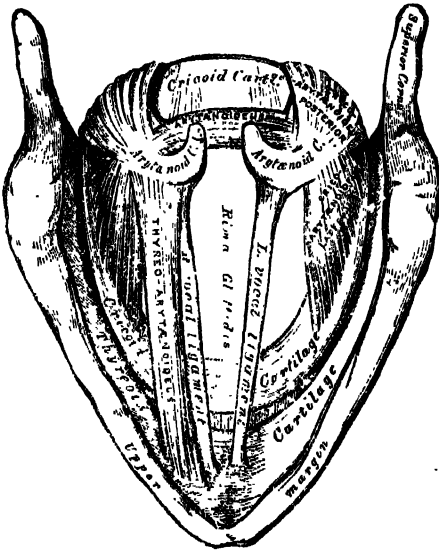


FIG. 948.—Muscles of the larynx, seen from above. (Enlarged.)

lateral margin of the Arytenoid cartilage to the side of the epiglottis, and constitute the *Ventricularis* muscle.

Actions.—The muscles of the larynx may be conveniently divided into two groups, (1) those which open and close the glottis, viz. the *Cricoarytænoidei posteriores* and *laterales* and the *Arytænoidei*; (2) those which regulate the degree of tension of the vocal ligaments, viz. the *Cricothyroidei*, the *Thyroarytænoidei*, and the *Vocales*.

The *Cricoarytænoidei posteriores* open the glottis, by rotating the arytenoid cartilages outwards around a vertical axis passing through the crico-arytenoid joints, so that the vocal processes and the attached vocal folds are separated.

The *Cricoarytænoidei laterales* close the glottis, by rotating the arytenoid cartilages inwards so as to approximate the vocal processes.

The *Arytænoidei* approximate the arytenoid cartilages, and thus close the opening of the glottis, especially at its posterior part.

The *Cricothyroidei* produce tension and elongation of the vocal ligaments by drawing up the arch of the cricoid cartilage and tilting back the upper border of its lamina; the distance between the vocal processes and the angle of the thyroid is thus increased, and the vocal ligaments are consequently elongated.

The *Thyroarytænoidei* draw the arytenoid cartilages forwards towards the thyroid, and thus shorten and relax the vocal ligaments. At the same time they rotate the arytenoid cartilages inwards and approximate the vocal folds. The deeper fibres, forming the *Vocales*, produce relaxation of the vocal ligaments.

The manner in which the entrance of the larynx is closed during deglutition is referred to on p. 1075.

Mucous Membrane.—The mucous membrane of the larynx is continuous above with that of the mouth and pharynx, below with that of the trachea. It covers, and is closely adherent to, the posterior surface and the upper part of the anterior surface of the epiglottis, and forms the aryepiglottic folds which bound the entrance of the larynx. It lines the cavity of the larynx; forms, by its reduplication, the chief parts of the ventricular folds, and is continued from the ventricle into the ventricular appendix. The parts covering the vocal ligaments are thin and intimately adherent to them. On the anterior surface, and the upper half of the posterior surface, of the epiglottis, the upper part of the aryepiglottic folds, and the vocal folds, the epithelium of the mucous membrane is of the stratified squamous type; patches of stratified squamous epithelium are also found above the glottis. The rest of the laryngeal mucous membrane is covered by columnar ciliated epithelium.

Glands.—The mucous membrane of the larynx is furnished with numerous mucous glands; they are very plentiful upon the epiglottis, where they are lodged in little pits; many are present in the margins of the aryepiglottic folds in front of the arytenoid cartilages, where they are termed the *arytenoid glands*. They are large and numerous in the ventricular appendices. The free edges of the vocal folds are devoid of glands.

Taste-buds, similar to those in the tongue, are found over the posterior surface of the epiglottis, in the aryepiglottic folds, and less regularly in some other parts of the larynx.

Vessels and Nerves.—The chief *arteries* of the larynx are the laryngeal branches of the superior and inferior thyroid arteries. The *veins* accompanying the superior laryngeal artery join the superior thyroid vein which opens into the internal jugular vein; those accompanying the inferior laryngeal artery join the inferior thyroid vein which opens into the innominate vein. The *lymphatic vessels* are divisible into two sets, a superior above, and an inferior below, the vocal folds: the superior vessels accompany the superior laryngeal artery, pierce the hyothyroid membrane, and end in the deep cervical lymph-glands situated near the bifurcation of the common carotid artery; some of the inferior lymphatic vessels pierce the middle cricothyroid ligament and open into a lymph-gland lying in front of that ligament or in front of the upper part of the trachea, while others emerge below the cricoid cartilage and pass to the deep cervical lymph-glands and to the lymph-glands alongside of the inferior thyroid artery. The *nerves* are derived from the internal and external branches of the superior laryngeal nerve, from the recurrent nerve and from the sympathetic. The internal laryngeal branch is almost entirely sensory, but some motor filaments are said to be carried by it to the Arytenoideus. It enters the larynx through the posterior part of the hyothyroid membrane above the superior laryngeal artery, and divides into three branches: one is distributed to both surfaces of the epiglottis, a second to the aryepiglottic fold, and a third, the largest, supplies the mucous membrane over the back of the larynx and communicates with the recurrent nerve. The external laryngeal branch supplies the Cricothyroideus by entering its lateral surface. The recurrent nerve passes upwards beneath the lower border of the Constrictor pharyngis inferior immediately behind the cricothyroid joint. It supplies all the intrinsic muscles of the larynx except the Cricothyroideus, and perhaps a part of the Arytenoideus. The sensory branches of the laryngeal nerves form sub-epithelial plexuses, from which fibres pass to end between cells covering the mucous membrane.

THE TRACHEA AND BRONCHI (fig. 949)

The trachea, or windpipe, is a cartilaginous and membranous tube, about 10 cm. long, continued downwards from the lower part of the larynx, and reaching from the level of the sixth cervical vertebra to that of the upper border of the fifth thoracic vertebra, where it divides into two bronchi, one for either lung. It is not quite cylindrical, being flattened posteriorly; its diameter, from side to side, is about 2 cm. in the male and 1.5 cm. in the female. In the child the trachea is smaller, more deeply placed and more movable than in the adult.

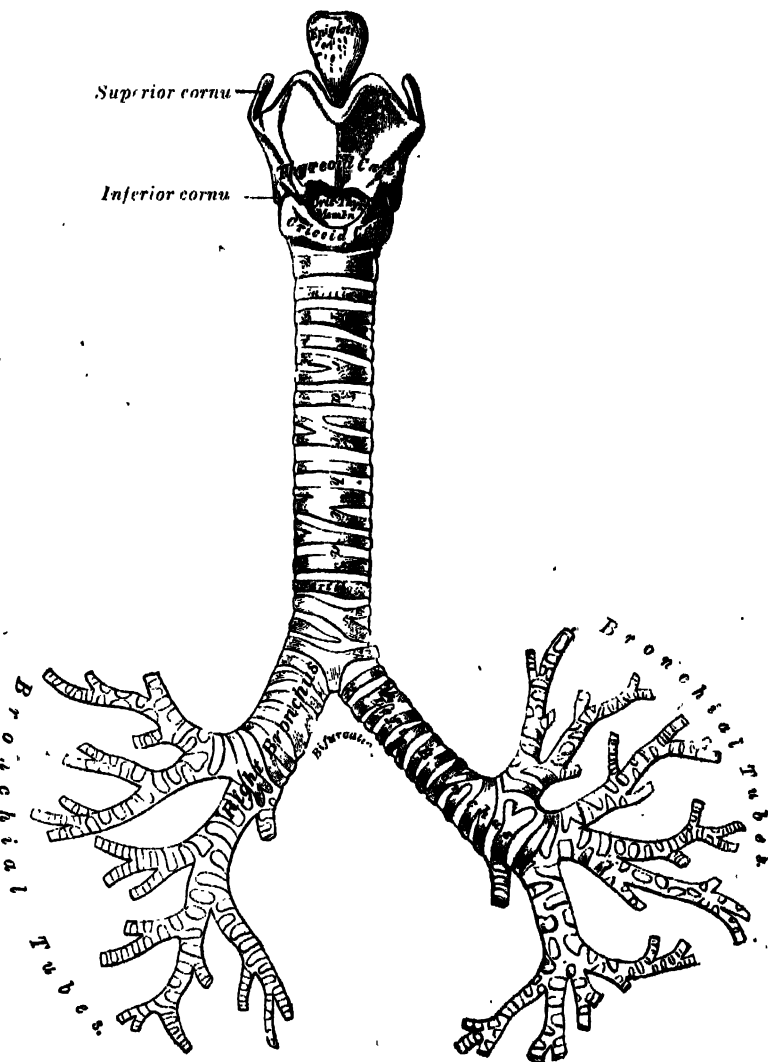
Relations.—In the neck its anterior surface is covered from above downwards, by the isthmus of the thyroid gland, the inferior thyroid veins, the *arteria thyroidea ima* (when that vessel exists), the Sternothyroideus and Sternohyoideus muscles, the fascia colli, and, more superficially, by the anastomosing branches between the anterior jugular veins. Laterally it is in relation with the common carotid arteries, the right and left lobes of the thyroid gland, the inferior thyroid arteries, and the recurrent nerves.

In the thorax it lies in the superior mediastinal cavity, and is covered from before backwards by the manubrium sterni, the remains of the thymus, the left innominate vein, the aortic arch, the innominate and left common carotid arteries, and the deep part of the cardiac plexus. Posteriorly it is in contact with the œsophagus. It is in relation on the right side with the pleura and

right vagus, and near the root of the neck with the innominate artery; on the left side with the left recurrent nerve, the aortic arch, and the left common carotid and subclavian arteries (fig. 954).

The right bronchus, wider, shorter, and more vertically directed than the left, is about 2.5 cm. long, and enters the right lung nearly opposite the fifth thoracic vertebra. The azygos vein arches over it from behind; and the right pulmonary artery lies at first below and then in front of it. About

FIG. 949.—A front view of the cartilages of the larynx, trachea, and bronchi.



2 cm. from its commencement it gives off a branch to the upper lobe of the right lung; this is termed the *eparterial branch*, because it arises above the right pulmonary artery. The bronchus now passes below the artery, and is known as the *hyparterial branch*; this divides into two branches for the middle and lower lobes of the lung.

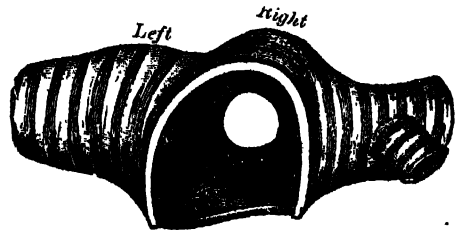
The left bronchus, narrower than the right, is nearly 5 cm. long, and enters the root of the left lung opposite the sixth thoracic vertebra. It passes beneath the aortic arch, and crosses in front of the oesophagus, the thoracic duct, and the descending aorta; the left pulmonary artery lies at first above, and then in front of it. The left bronchus has no *eparterial branch*, and therefore

it has been supposed by some that there is no upper lobe to the left lung, and that the so-called upper lobe corresponds to the middle lobe of the right lung.

The further subdivision of the bronchi will be considered with the structure of the lung.

If the trachea be cut across a short distance above its bifurcation, and the interior of the lower part viewed from above (fig. 950), it will be seen that, in most cases, the septum between the two bronchi lies on the left of the median plane, and the right bronchus appears to be a more direct continuation of the trachea than the left.

FIG. 950.—A transverse section of the trachea, just above its bifurcation.

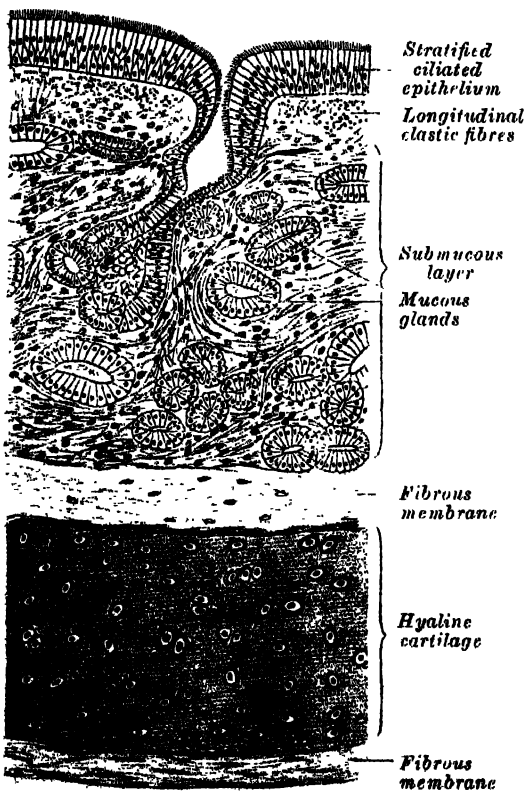


A solid body dropping into the trachea would naturally be directed towards the right bronchus. This tendency is aided by the larger diameter of the right tube as compared with its fellow. These facts serve to explain why a foreign body in the trachea usually falls into the right bronchus.

Structure (fig. 951).—The trachea and extrapulmonary bronchi consist of a framework of imperfect rings of hyaline cartilage, united by fibrous and unstriped muscular tissue. They are lined by mucous membrane.

The cartilages of the trachea vary from sixteen to twenty in number. Each is an imperfect ring which occupies the anterior two-thirds or so of the circumference of the trachea;

FIG. 951.—A transverse section of the trachea.



are deficient, the tube is completed by fibrous tissue and unstriped muscular fibres. The cartilages are placed horizontally above one another, and are separated by narrow intervals. They measure about 4 mm. in depth and 1 mm. in thickness; their external surfaces are flattened in a vertical direction, but their internal are convex. Two or more of the cartilages often unite, partially or completely, and they are sometimes bifurcated at their extremities. They are highly elastic, but may become calcified in advanced life. In the right bronchus the cartilages vary in number, from six to eight; in the left, from nine to twelve. They are shorter and narrower than those of the trachea, but have the same shape and arrangement. The first and the last tracheal cartilages differ from the others (fig. 949).

The first cartilage is broader than the rest, and often divided at one end; it is connected by the cricotracheal ligament with the lower border of the cricoid cartilage, with which, or with the succeeding cartilage, it is sometimes blended.

The last cartilage is thick and broad in the middle, in consequence of its lower border being prolonged into a triangular hook-

shaped process which curves downwards and backwards between the two bronchi. It forms on each side an imperfect ring which encloses the commencement of the bronchus. The cartilage above the last is somewhat broader at its centre than the others.

The fibrous membrane.—The cartilages are enclosed in an elastic fibrous membrane, which consists of two layers, one, the thicker, passing over the outer surfaces of the rings, the other over the inner surfaces: at the upper and lower margins of the cartilages the two layers blend and form a stout membrane which connects the rings one with

another. Where the cartilages are deficient posteriorly the membrane forms a single layer.

The *muscular tissue* is placed within the fibrous membrane at the posterior part of the tube, and consists of two layers of non-striped muscle, longitudinal and transverse. The *longitudinal fibres* are external, and consist of a few scattered bundles. The *transverse fibres* (Trachealis muscle) are internal, and form a thin layer which not only extends between the ends of the cartilages but also passes across in the intervals between the cartilages.

Mucous Membrane.—The mucous membrane is continuous above with that of the larynx, and below with that of the bronchi. It consists of areolar and lymphoid tissue, and presents a well-marked basement membrane, supporting a stratified epithelium, the surface layer of which is columnar and ciliated, while the deeper layers consist of oval or rounded cells. Beneath the basement membrane there is a layer of longitudinal elastic fibres with a small amount of intervening areolar tissue. The *submucous layer* is composed of a loose meshwork of connective tissue, containing large blood-vessels, nerves, and mucous glands; the ducts of the latter pierce the overlying layers and open into the trachea (fig. 951).

Vessels and Nerves.—The trachea is supplied with blood mainly by the inferior thyroid arteries. The veins end in the thyroid venous plexus. The nerves are derived from the vagi and the recurrent nerves, and from the sympathetic trunks; they are distributed to the Trachealis muscle and between the epithelial cells.

Applied Anatomy.—Foreign bodies often find their way into the air-passages, and may consist of large soft substances, as pieces of meat, which may become lodged in the entrance of the larynx, or in the rima glottidis, and cause speedy suffocation unless rapidly got rid of, or unless an opening is made into the air-passages below the obstruction, so as to enable the patient to breathe. Smaller bodies, frequently of a hard nature, such as cherry or plum stones, small pieces of bone, buttons, &c., may find their way through the rima glottidis into the trachea or bronchi, or may lodge in the ventricle of the larynx. The dangers then depend not so much upon the mechanical obstruction as upon reflex spasm of the glottis produced by the irritation of the foreign body. When lodged in the ventricle of the larynx the foreign body may produce few symptoms, beyond sudden loss of voice or alteration in the voice sounds. When, however, it is situated in the trachea, it is constantly striking against the vocal folds during expiratory efforts, and thus produces attacks of dyspnoea from spasm of the glottis. When lodged in the bronchus, it usually becomes fixed there, and, occluding the lumen of the tube, causes a loss of the respiratory murmur on the affected side, and may subsequently lead to purulent bronchitis and gangrene of the lung. Foreign bodies should always be removed from the air passages as soon as possible.

Beneath the mucous membrane of the upper part of the air-passages there is a considerable amount of submucous tissue, which is liable to become much swollen from effusion in inflammatory affections, constituting the condition known as 'œdema of the glottis.' This effusion does not extend below the level of the vocal folds, on account of the fact that the mucous membrane is closely adherent to these structures without the intervention of any submucous tissue. In cases of œdema of the glottis, in which it is necessary to open the air-passages to prevent suffocation, the operation of laryngotomy is sufficient. Laryngeal or glottidean œdema may be secondary to some local inflammatory affection such as acute septic laryngitis, syphilitic laryngeal perichondritis, or malignant disease; or the œdema may be passive (non-inflammatory), consequent upon renal or cardiac mischief, angioneurotic œdema.

Ulceration of the larynx may occur from syphilis, either as a superficial ulceration, or from the softening of a gumma; from tuberculous disease (laryngeal phthisis), or from malignant disease (epithelioma).

The air-passages may be opened in three different situations: by a vertical incision through the centre of the thyroid cartilage (*thyrotomy*); through the middle cricothyroid ligament (*laryngotomy*); or in some part of the trachea (*tracheotomy*).

Thyrotomy is usually performed for the purpose of removing growths from the vocal folds or for extracting foreign bodies from the ventricle of the larynx. A median incision is made from the upper border of the body of the hyoid bone to the lower border of the cricoid cartilage, and is carried through the subcutaneous tissues and deep fascia between the margins of the Sternohyoidæ. An incision is then made in the middle cricothyroid ligament, and one blade of a stout, sharp-pointed pair of scissors is introduced beneath the lower border of the thyroid cartilage, and this structure is divided from below upwards. Great care must be taken to cut exactly in the middle line to avoid wounding the vocal folds. If the halves of the cartilage are now drawn apart, a very good view of the interior of the larynx will be obtained.

Laryngotomy is a simple operation, and should be performed in those cases where the air-passages require to be opened in an emergency for the relief of some sudden obstruction to respiration. The middle cricothyroid ligament is very superficial, being covered only by the skin, superficial fascia, and the deep fascia in the middle line. On either side it is also covered by the Sternohyoidæus and Sternothyroidæus, which diverge from each other at their upper parts, leaving a slight interval between them. On

these muscles rest the anterior jugular veins. The cricothyroid artery crosses the middle cricothyroid ligament, and may be wounded, but rarely gives rise to any trouble. The operation is performed thus: the head being thrown back and steadied by an assistant, the finger is passed over the front of the neck, and the cricothyroid depression felt for. A vertical incision is then made through the skin in the middle line over this spot, and carried down through the fascia until the middle cricothyroid ligament is exposed. A cross-cut is then made through the ligament close to the upper border of the cricoid cartilage, so as to avoid, if possible, the cricothyroid artery, and a laryngotomy tube inserted. It has been recommended, as a more rapid way of performing the operation, to make a transverse instead of a longitudinal cut through the superficial structures, and thus to open at once the air-passages. It will be seen, however, that in operating in this way the anterior jugular veins are in danger of being wounded.

Tracheotomy may be performed either above or below the isthmus of the thyroid gland, or this structure may be divided and the trachea opened behind it. From the relations already described it must be evident that the trachea can be more readily opened above than below the isthmus.

Tracheotomy above the isthmus is performed thus: the patient should, if possible, be laid on his back on a table in a good light. A pillow is to be placed under the shoulders and the head thrown back and steadied by an assistant. The surgeon standing on the right side of his patient makes an incision from 1 cm. to 5 cm. long in the median line of the neck from the top of the cricoid cartilage. After the superficial structures have been divided, the interval between the Sternohyoidei must be found, the fascia divided, and the muscles drawn apart. The lower border of the cricoid cartilage must now be felt for, and the upper part of the trachea exposed from this point downwards in the middle line. It has been recommended that the layer of fascia in front of the trachea should be divided transversely at the level of the lower border of the cricoid cartilage, and, having been seized with a pair of forceps, pressed downwards with the handle of the scalpel. By this means the isthmus of the thyroid gland is depressed, and is saved from all danger of being wounded, and the trachea cleanly exposed. The trachea is now transfixed with a sharp hook and drawn forwards in order to steady it, and is then opened by inserting the knife into it and dividing the upper two or three rings by cutting upwards. If the trachea is to be opened beneath the isthmus of the thyroid gland, the incision must be made from a little below the cricoid cartilage to the top of the sternum; in this situation the trachea is situated more deeply.

A portion or the whole of the larynx may be removed for malignant disease. It may be removed by a median incision through the soft parts, freeing the cartilages from the muscles and other structures in front, separating the larynx from the trachea below, and dissecting it off from the deeper structures from below upwards.

THE PLEURÆ

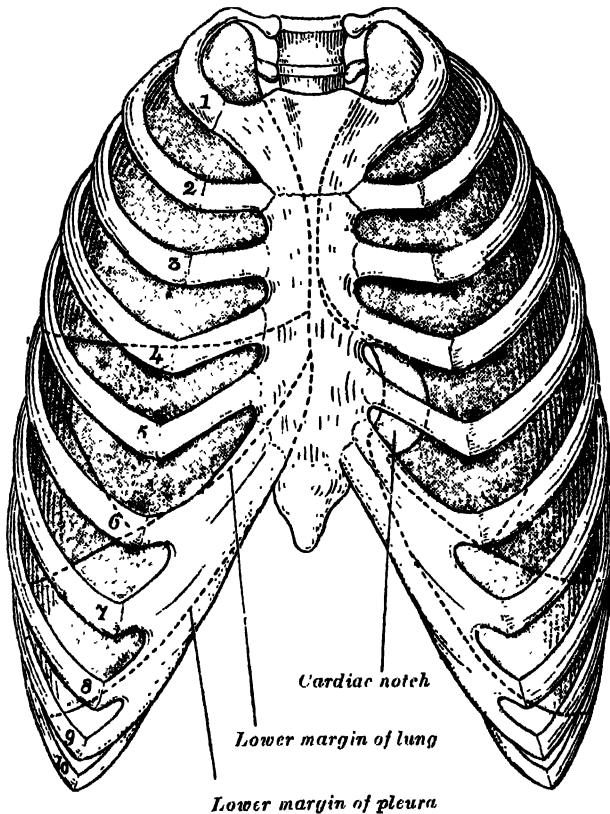
Each lung is invested by a delicate serous membrane, the **pleura**, which is arranged in the form of a closed invaginated sac. A portion of the serous membrane covers the surface of the lung and dips into the fissures between its lobes; it is called the *pulmonary pleura*. The rest of the membrane lines the inner surface of the chest-wall, covers the Diaphragm, and is reflected over the structures occupying the middle of the thorax; this portion is termed the *parietal pleura*. The two portions are continuous with one another round and below the root of the lung; in health they are in actual contact, but the potential space between them is known as the *pleural cavity*. When the lung collapses or when air or fluid collects between the two portions the cavity becomes apparent. The right and left pleural sacs are distinct from one another, and only touch each other for a short distance in front, opposite the second and third pieces of the sternum. The interval between the two sacs is termed the mediastinal cavity. The right pleural sac is shorter, wider, and reaches higher in the neck than the left.

Pulmonary pleura.—The *pulmonary pleura* is inseparably connected with the lung. It covers the surfaces of the lung, including those which bound the fissures between the lobes of the lung; it is wanting only at an area where the lung root enters and along a line extending downwards from this and marking the attachment of the pulmonary ligament.

Parietal pleura.—Different portions of the parietal pleura have received special names, which indicate their positions; that lining the inner surfaces of the ribs and Intercostales is the *costal pleura*; that clothing the thoracic surface of the Diaphragm is the *diaphragmatic pleura*; that which ascends into the neck over the summit of the lung is the *cupula of the pleura*; and that which is applied to the other thoracic viscera is the *mediastinal pleura*.

Costal pleura (figs. 952, 953).—The costal pleura lines the ribs and intercostal muscles, and is easily separated from them. In front it begins behind the sternum where it is continuous with the mediastinal pleura. The line of junction of the two parts extends from behind the sternoclavicular joint downwards and medialwards to reach a point in the middle line behind the sternal angle. From this point the line differs on the two sides. On the right side it is continued down to the posterior surface of the xiphoid process. On the left it descends to the level of the fourth or the upper border of the fifth costal cartilage and then diverges lateralwards and is continued down close to the lateral margin of the sternum to the level of the sixth costal cartilage. On

FIG. 952.—A front view of the thorax, showing the relations of the pleuræ and lungs to the chest wall.



Pleuræ in blue ; lungs in purple.

either side the costal pleura sweeps lateralwards, lining the inner surfaces of the costal cartilages, ribs and Intercostales, and at the back of the thorax passes over the sympathetic trunk and its branches, and on to the sides of the bodies of the vertebræ, where it again becomes continuous with the mediastinal pleura. Above, the costal pleura is continuous with the cupula of the pleura at the inner margin of the first rib. Below, it is continuous with the diaphragmatic pleura along a line which differs slightly on the two sides. On the right side the line begins behind the xiphoid process, and runs downwards and backwards behind the seventh costal cartilage, and reaches the mid-axillary line at the level of the tenth rib ; from here the line ascends somewhat to reach the level of the spinous process of the twelfth thoracic vertebra. On the left side the line follows at first the ascending part of the sixth costal cartilage, but in the rest of its course is slightly lower than that on the right side.

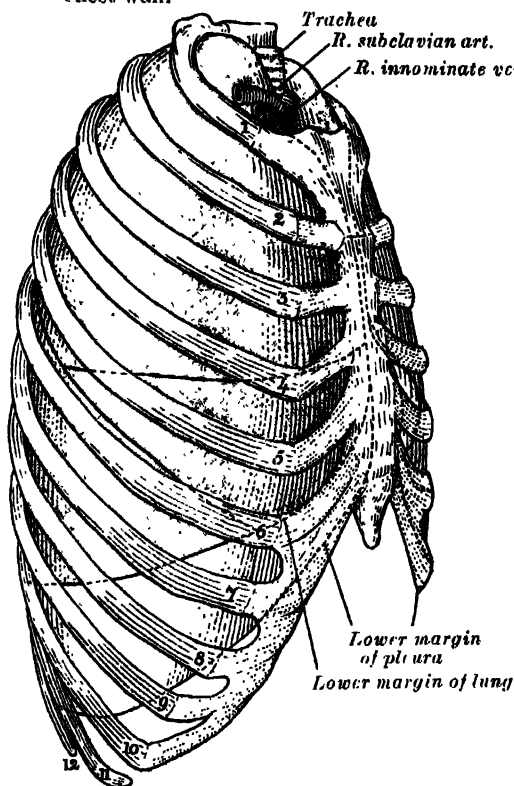
Diaphragmatic pleura.—The diaphragmatic pleura is thin, and covers the upper surface of its corresponding side of the Diaphragm. The outer part of its circumference is the line described above, along which it is continuous with the costal pleura. Medially it is continuous with the mediastinal pleura along the line of attachment of the pericardium to the Diaphragm.

Cupula of the pleura.—This, the cervical portion of the pleura, is the continuation of the costal pleura over the apex of the lung. It begins along the inner border of the first rib and extends medialwards and upwards to the apex of the lung; it then descends along the side of the trachea to become continuous with the mediastinal pleura. The cupula of the pleura is strengthened by a dome-like expansion of fascia (*Sibson's fascia*) attached in front to the inner border of the first rib and behind to the anterior border of the transverse process of the seventh cervical vertebra; it is covered and strengthened by a few spreading muscular fibres derived from the Scaleni.

Mediastinal pleura.—The mediastinum or middle portion of the thorax contains the heart, enclosed in its pericardium, the great vessels entering and leaving the heart, and the œsophagus together with other structures described on p. 1035. Over these is placed the mediastinal pleura. Above, it is continuous with the cupula of the pleura; below, with the diaphragmatic pleura; in front and behind, with the costal pleura. Its arrangement is complicated by the fact that the structures forming the root of the lung (viz. bronchus, pulmonary vessels, &c.) carry forward this part of the pleura to the surface of the lung. Above the root of the lung the mediastinal pleura is a continuous sheet between the sternum and vertebral column. At the root of the lung it is carried lateralwards as a tube of serous membrane enclosing the structures of the lung-root and passing into continuity with the pulmonary pleura. Below the lung-root the mediastinal pleura extends as a bilaminar layer from the side of the pericardium to the mediastinal surface of the lung, where it is also continuous with the pulmonary pleura. This bilaminar layer is continuous above with the tube investing the lung root; below it ends in a free falciform border. It is named the *pulmonary ligament*, and serves to retain the lower part of the lung in position.

The inferior limit of the pleura is on a considerably lower level than the corresponding border of the lung, but does not extend to the attachment of the Diaphragm, so that below the line of reflection of the pleura from the chest-wall to the Diaphragm the latter is in direct contact with the rib cartilages and the *Intercostales interni*. Moreover, in ordinary inspiration the thin inferior margin of the lung does not extend as low as the line of the pleural reflection, with the result that the costal and diaphragmatic pleuræ are here in contact, the intervening narrow slit being termed the *phrenicocostal sinus*.

FIG. 953.—A lateral view of the thorax, showing the relations of the pleuræ and lungs to the chest wall.



Pleuræ in blue; lungs in purple.

A similar condition exists behind the sternum and rib cartilages, where the anterior thin margin of the lung falls short of the line of pleural reflection, and where the slit-like cavity between the two layers of pleura forms what is called the *costomediastinal sinus*.

Structure.—The free surface of the pleura is smooth, and moistened by serous fluid. Like other serous membranes, it is covered by a single layer of flattened nucleated cells, united at their edges by cement substance. These cells are modified connective tissue corpuscles, and rest on a basement membrane. Beneath the basement membrane there are networks of yellow elastic and white fibres, imbedded in ground substance which also contains connective tissue cells. Blood-vessels, lymphatics, and nerves are distributed in the substance of the pleura, and the lymphatics communicate with the pleural cavity by means of stomata or openings between the flattened cells.

Vessels and Nerves.—The arteries of the pleura are derived from the intercostal, internal mammary, musculophrenic, thymic, pericardiac, and bronchial vessels. The veins correspond to the arteries. The lymphatics are described on p. 739. The nerves are derived from the phrenic nerve and from the sympathetic trunk. Kölliker states that nerves accompany the ramifications of the bronchial arteries in the pulmonary pleura.

Applied Anatomy.—Acute inflammation of the pleura, or *pleurisy*, may be either dry or wet, and, if wet, either serous or purulent. *Dry pleurisy* is common in pneumonia, and is often an early manifestation of tuberculosis. It gives rise to much pain, and to friction sounds due to the scraping to and fro over one another of the inflamed and roughened parietal and pulmonary pleurae. *Wet pleurisy* occurs if the inflammation causes the effusion of serum into the pleural cavity. The two pleural layers are now separated by the fluid effusion, so the friction sounds are no longer produced. Room is found for the fluid by shrinkage of the supernatant lung due to the retraction of its elastic tissue, and later, when the quantity of serum exceeds about 1·5 litre, by shifting over of the heart and unaffected lung towards the sound side. This shifting may be so extensive that the apex beat of the heart comes to lie under the right mammary papilla. Any pleural effusion that is large enough to embarrass respiration seriously, or has remained unabsorbed for two or three weeks, should be removed by tapping (paracentesis thoracis). The trocar is pushed through the chest-wall into the fluid, in the sixth or seventh intercostal space in the midaxillary line, or in the eighth or ninth space just outside the angle of the scapula. Aspiration is then performed, and as much fluid as possible drawn off: it must be stopped, however, if the patient shows signs of collapse, or if fits of coughing occur and threaten to wound the expanding lung against the sharp end of the trocar. Non-inflammatory or passive effusion into the pleura, called *hydrothorax*, is often seen in the later stages of chronic renal or cardiac disease, and demands treatment on lines similar to the above.

Purulent pleural effusion, or *empyema*, often occurs after such diseases as pneumonia or measles. This condition requires drainage of the cavity, which usually necessitates excision of a portion of a rib. An incision is made down to the seventh or eighth rib in the mid- or posterior axillary line and the periosteum is incised, and separated from the body of the rib, carrying with it the structures in the costal groove. With bone-cutting forceps about 4 cm. or 5 cm. of the rib are separated and removed, and the underlying pleura is incised. The pus having been evacuated, a large drainage tube is inserted into the cavity. The pleura should never be irrigated, as sudden death has followed this proceeding, and great care should be taken to prevent the tube from slipping into the cavity, an occurrence which is far from uncommon.

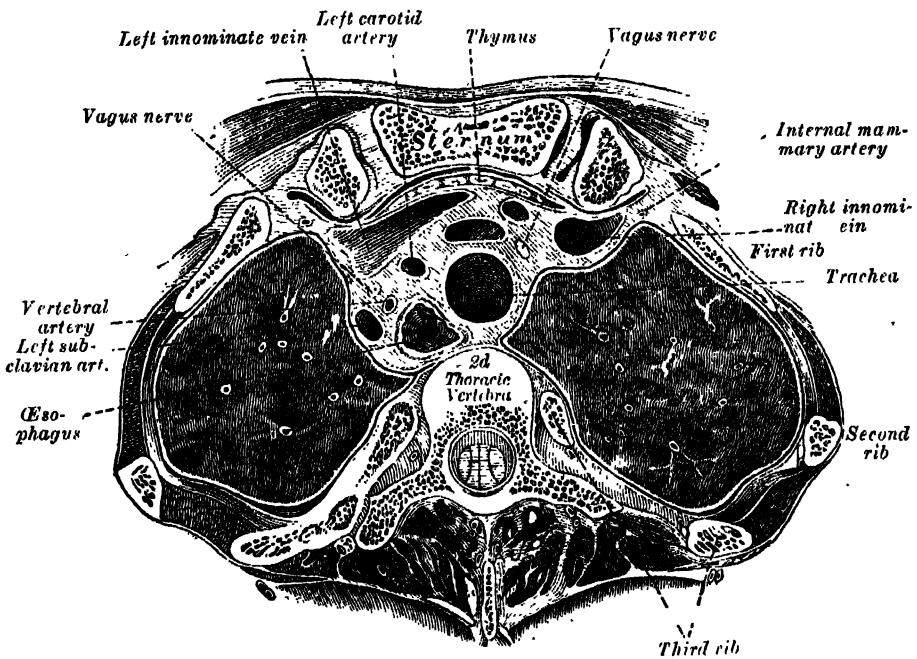
Pneumothorax, or the presence of gas in the pleural cavity, is a common terminal event in tuberculosis of the lungs; less often it is due to trauma—rupture of the lung, for example, when the chest is crushed, or tearing of the lung-tissue by the sharp projecting end of a broken rib. Air escapes from the lung into the pleural cavity; the elastic tissue of the lung at once contracts, and finally that organ shrinks away to a dark rounded mass the size of a fist, lying close against the vertebral column. The symptoms of pneumothorax are often very severe; cyanosis, intense dyspnoea, great pain on the affected side, and cardiac failure. Their severity is increased by the fact that the blood-vessels of the collapsed lung offer less resistance to the circulation of the blood than do those of the other lung. Not only, therefore, does the sound lung suddenly have to take over the work—the aeration of the blood—normally performed by both lungs, but it has to do so at the moment when the circulation of blood through it is partially short-circuited by the collapsed lung. If the patient survives for a few days, empyema often complicates the pneumothorax, setting up the condition called *pyopneumothorax*. During the last few years a valuable method of treating selected cases of pulmonary tuberculosis by the establishment and maintenance of an artificial pneumothorax on the affected side, causing collapse of the diseased lung, has been employed.

In operations upon the kidney, it must be borne in mind that the pleural cavity usually extends below the level of the medial portion of the last rib, and may therefore be opened in these operations, especially when the last rib is removed in order to give more room.

THE MEDIASTINAL CAVITY

The **mediastinal cavity** is the space between the right and left pleuræ. It extends from the sternum in front to the vertebral column behind, and contains all the thoracic viscera except the lungs. The cavity may be divided for purposes of description into two parts: an upper, the *superior mediastinal cavity*, above the pericardium, and a lower, which is subdivided into three parts, viz.: that in front of the pericardium, the *anterior mediastinal cavity*; that containing the pericardium and its contents, the *middle mediastinal cavity*; and that behind the pericardium, the *posterior mediastinal cavity*.

FIG. 954.—A transverse section through the thorax at the level of the upper margin of the second thoracic vertebra. (Braune.)



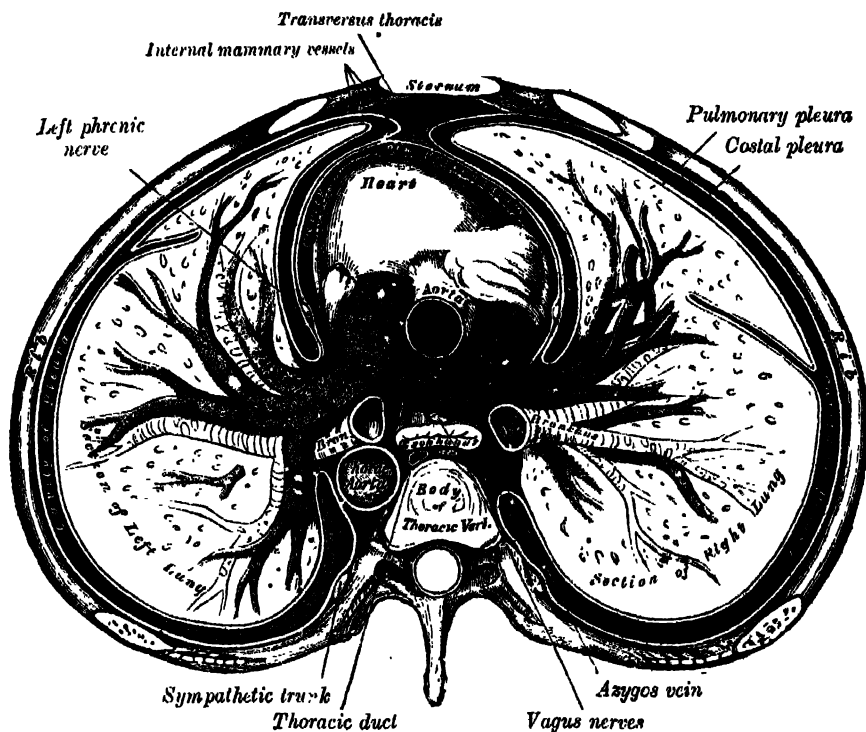
The **superior mediastinal cavity** (fig. 954) lies between the manubrium sterni in front, and the upper four thoracic vertebrae behind. It is bounded below by a slightly oblique plane passing from the junction of the manubrium and body of the sternum to the lower part of the body of the fourth thoracic vertebra, and laterally by the pleuræ; above, by the plane of the thoracic inlet. It contains the origins of the Sternohyoidei and Sternothyroidei and the lower ends of the Longi colli; the aortic arch; the innominate artery and the thoracic portions of the left common carotid and the left subclavian arteries; the innominate veins and the upper half of the superior vena cava; the left first intercostal vein; the vagus, cardiac, phrenic, and left recurrent nerves; the trachea, œsophagus, and thoracic duct; the remains of the thymus, and some lymph-glands.

The **anterior mediastinal cavity** (fig. 955) exists only on the left side where the left pleura diverges from the mid-sternal line. It is bounded in front by the sternum, laterally by the pleuræ, and behind by the pericardium. It is narrow above, but widens out a little below. Its anterior wall is formed by the left Transversus thoracis muscle and the fifth, sixth, and seventh left costal cartilages. It contains a quantity of loose areolar tissue, some lymphatic vessels which ascend from the convex surface of the liver, two or three anterior mediastinal lymph-glands, and the small mediastinal branches of the internal mammary artery.

The **middle mediastinal cavity** (fig. 955) is the broadest part of the interpleural space. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the superior vena cava, the terminal part of the azygos vein, the bifurcation of the trachea, the two bronchi, the pulmonary artery dividing into its right and left branches, the right and left pulmonary veins, the phrenic nerves, and some tracheobronchial lymph-glands.

The **posterior mediastinal cavity** (figs. 955, 956) is an irregularly shaped space running parallel with the vertebral column; it is bounded in front by the pericardium above, and by the posterior surface of the Diaphragm below,

FIG. 955.—A diagram of a transverse section of the thorax, showing the contents of the middle and posterior mediastinal cavities.

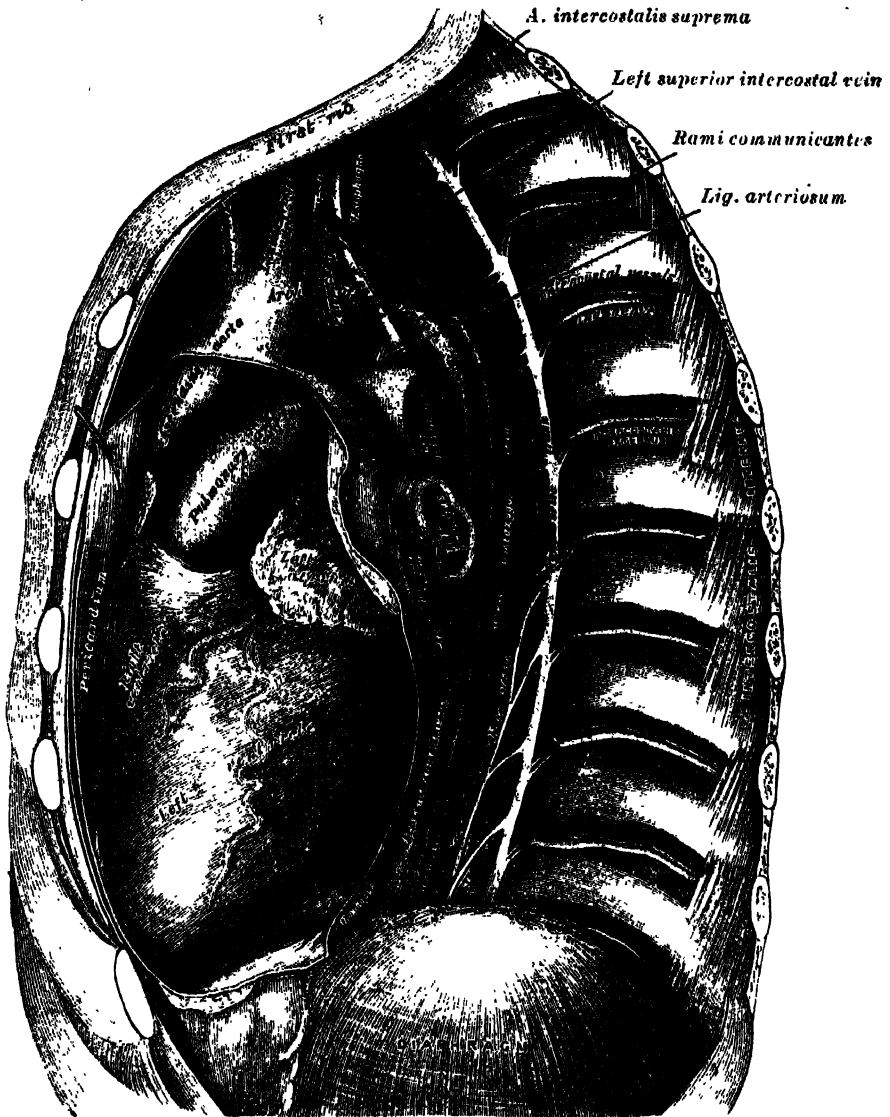


behind by the vertebral column from the lower border of the fourth to the twelfth thoracic vertebra, and on either side by the mediastinal pleura. It contains the thoracic part of the descending aorta, the azygos, hemiazygos, and accessory hemiazygos veins, the vagus and splanchnic nerves, the œsophagus, the thoracic duct, and some lymph-glands.

Applied Anatomy.—Primary tumours of the mediastinum are usually sarcoma or carcinoma arising from the thymus or the mediastinal lymph-glands. Lymphosarcoma, embryoma, and dermoid cysts occur more rarely. These tumours give rise to pain, deformity of the chest, and symptoms of pressure on the nerves, blood-vessels, air-passages, lymphatics, and on the œsophagus, as these various structures pass through the thorax. They may produce physical signs very much like those of an aortic aneurysm, so that diagnosis between the two is often difficult. The prognosis is bad, the condition usually proving fatal within a few months or a year of the onset of the symptoms.

Inflammation of the mediastinum due to wounds, or to the spread of inflammation from adjacent parts (e.g. the œsophagus, the pericardium), is sometimes acute, leading to abscess-formation. A more chronic form associated with adhesions and inflammation of the pericardium—the so-called chronic adhesive mediastinopericarditis—gives rise to obscure symptoms suggesting gradual heart-failure, and leads to death slowly but surely,

FIG. 956.—The superior, middle and posterior mediastinal cavities, viewed from the left side.



THE LUNGS (PULMONES)

The lungs are the essential organs of respiration ; they are two in number, placed one on either side within the thorax, and separated from each other by the heart and other contents of the mediastinal cavity (fig. 957). The substance of the lung is of a light, porous, spongy texture ; it floats in water, and crepitates when handled, owing to the presence of air in its alveoli ; it is also highly elastic ; hence the retracted state of these organs when they are removed from the closed cavity of the thorax. The surface is smooth, shining, and marked out into numerous polyhedral areas, indicating the lobules of the organ ; each of these areas is crossed by numerous lighter lines.

At birth the lungs are pinkish-white in colour ; in adult life the colour is a dark slaty-grey, mottled in patches ; and as age advances, this mottling assumes a black colour. The colouring matter consists of granules of a carbonaceous substance deposited in the areolar tissue near the surface of the

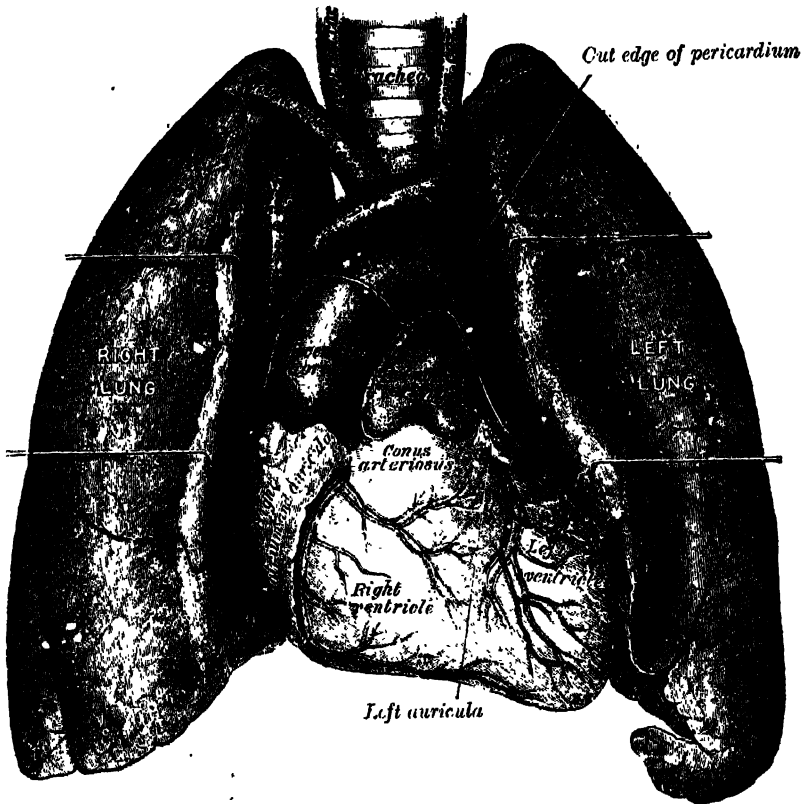
organ ; it increases in quantity as age advances, and is more abundant in males than in females. As a rule, the posterior border of the lung is darker than the anterior.

The right lung usually weighs about 625 gm., the left 567 gm., but much variation is met with according to the amount of blood or serous fluid they may contain. The lungs are heavier in the male than in the female, their proportion to the body being, in the former, as 1 to 37, in the latter as 1 to 43.

Each lung is conical in shape, and has an apex, a base, three borders, and two surfaces.

The *apex* is rounded, and extends into the root of the neck, reaching from 3 cm. to 4 cm. above the level of the sternal end of the first rib. A sulcus

FIG. 957.—A front view of the heart and lungs.



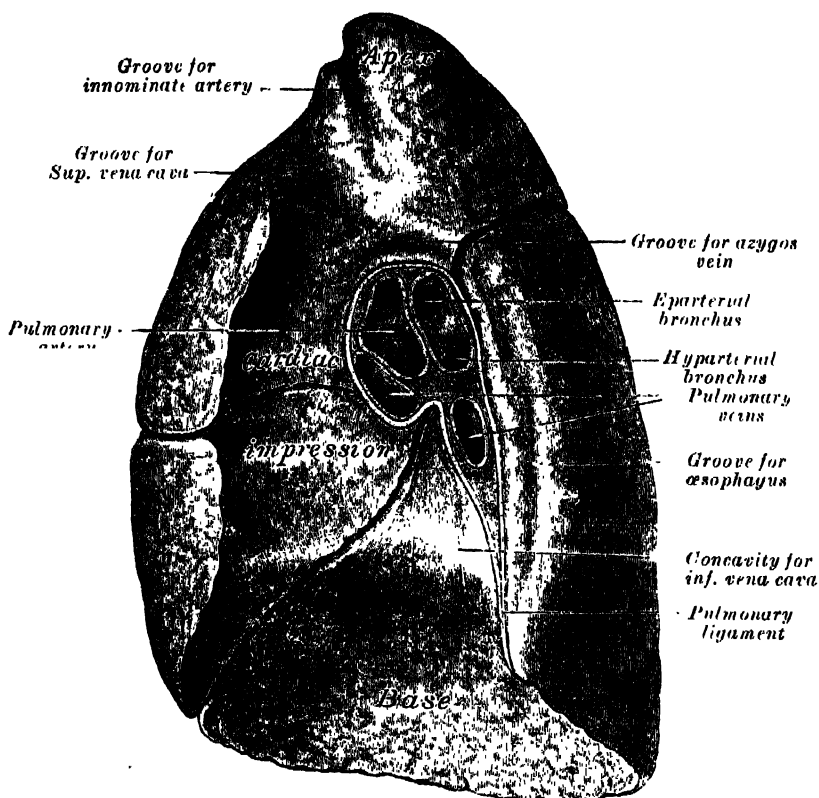
runs upwards and lateralwards immediately below the apex ; on the right lung this sulcus is produced by the innominate artery, on the left by the subclavian artery.

The *base* is broad, concave, and rests upon the convex surface of the Diaphragm, which separates the right lung from the right lobe of the liver, and the left lung from the left lobe of the liver, the stomach, and the spleen. Since the Diaphragm extends higher on the right than on the left side, the concavity on the base of the right lung is deeper than that on the left. Laterally and behind, the base is bounded by a thin, sharp margin which projects for some distance into the phrenicocostal sinus of the pleura, between the lower ribs and the costal attachment of the Diaphragm.

The *costal surface* is smooth, convex, of considerable extent, and corresponds to the form of the cavity of the chest, which is deeper behind than in front. It is in contact with the costal pleura, and exhibits, in specimens which have been hardened *in situ*, slight grooves corresponding with the overlying ribs.

The *mediastinal surface* is in contact with the mediastinal pleura. On it is a deep concavity, the *cardiac impression*, which accommodates the pericardium; this concavity is larger and deeper on the left than on the right lung, because the heart projects farther to the left than to the right side of the median plane. Above and behind this concavity is a triangular depression named the *hilum*, where the structures which form the root of the lung (p. 1041) enter and leave the viscus. These structures are invested by pleura, which, below the hilum and behind the pericardial impression, forms the pulmonary ligament. On the *right lung* (fig. 958), immediately above the hilum, is an arched furrow which accommodates the azygos vein; while running upwards, and then arching lateralwards some little distance below the apex, is a wide

FIG. 958.—The mediastinal surface of the right lung.



groove for the superior vena cava and right innominate vein; behind this, and nearer the apex, is a furrow for the innominate artery. Behind the hilum and the attachment of the pulmonary ligament is a vertical groove for the œsophagus; this groove becomes less distinct below, owing to the inclination of the lower part of the œsophagus to the left of the middle line. In front and to the right of the lower part of the œsophageal groove is a deep concavity for the extrapericardiac portion of the thoracic part of the inferior vena cava. On the *left lung* (fig. 959), immediately above the hilum, is a well-marked curved furrow produced by the aortic arch, and running upwards from this towards the apex is a groove accommodating the left subclavian artery; a slight impression in front of the latter and close to the margin of the lung lodges the left innominate vein. Behind the hilum and pulmonary ligament is a vertical furrow produced by the descending aorta; and in front of this, near the base of the lung, the lower part of the œsophagus causes a shallow impression.

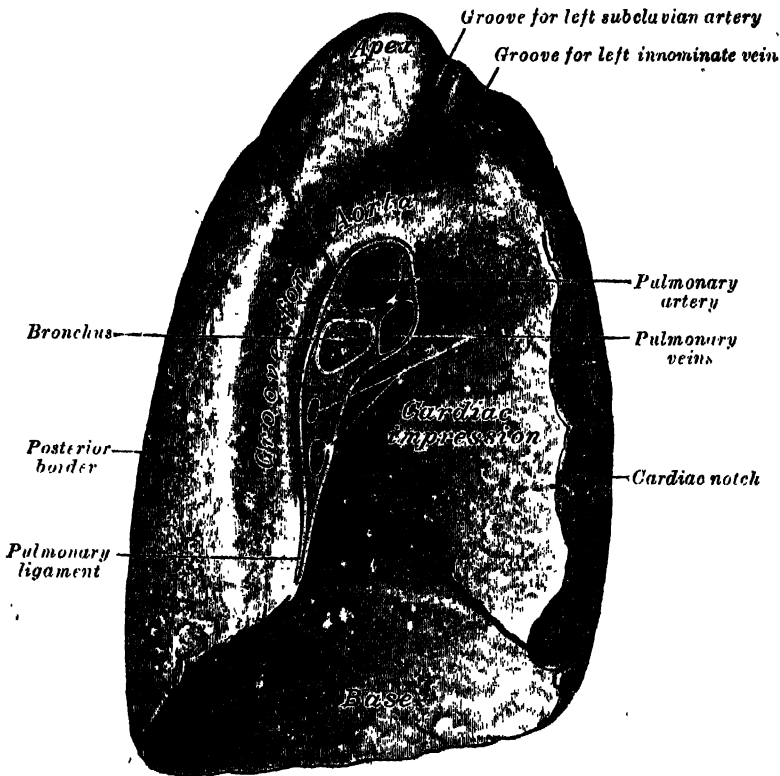
The *inferior border* is thin and sharp where it separates the base from the costal surface and extends into the phrenicocostal sinus; medially, where it

divides the base from the mediastinal surface, it is blunt and rounded. The *posterior border* is broad and rounded, and is received into the deep concavity on either side of the vertebral column. It is much longer than the anterior border, and projects, below, into the phrenicocostal sinus.

The *anterior border* is thin and sharp, and overlaps the front of the pericardium; that of the *right lung* is almost vertical, and projects into the costo-mediastinal sinus; that of the *left* presents, below, an angular notch, the *cardiac notch*, in which the pericardium is exposed. Opposite this notch the anterior margin of the left lung is situated some little distance laterally to the line of reflection of the corresponding part of the pleura.

Fissures and lobes of the lungs.—The *left lung* is divided into two lobes, an upper and a lower, by a fissure which extends from the costal to the medi-

FIG. 959.—The mediastinal surface of the left lung.



astinal surface of the lung both above and below the hilum. As seen on the surface, this fissure begins on the mediastinal surface of the lung at the upper and posterior part of the hilum, and runs backwards and upwards to the posterior border, which it crosses at a point about 6 cm. below the apex. It then extends downwards and forwards over the costal surface, and reaches the lower border a little behind its anterior extremity, and its further course can be followed upwards and backwards across the mediastinal surface as far as the lower part of the hilum. The *superior lobe* lies above and in front of this fissure, and includes the apex, the anterior border, and a considerable part of the costal surface and the greater part of the mediastinal surface of the lung. The *inferior lobe*, the larger of the two, is situated below and behind the fissure, and comprises almost the whole of the base, a large portion of the costal surface, and the greater part of the posterior border.

The *right lung* is divided into three lobes, superior, middle, and inferior, by two fissures. One of these separates the inferior from the middle and superior lobes, and corresponds closely with the fissure in the left lung. Its direction

is, however, more vertical, and it cuts the lower border about 7.5 cm. behind its anterior extremity. The other fissure separates the superior from the middle lobe. It begins in the previous fissure near the posterior border of the lung, and, running horizontally forwards, cuts the anterior border on a level with the sternal end of the fourth costal cartilage; on the mediastinal surface it may be traced backwards to the hilum. The *middle lobe* of the right lung is small and wedge-shaped, and includes the lower part of the anterior border and the anterior part of the base of the lung.

The right lung, although shorter by 2.5 cm. than the left, in consequence of the Diaphragm rising higher on the right side to accommodate the liver, is broader, owing to the inclination of the heart to the left side; its total capacity and weight are greater than those of the left lung.

Roots of the lungs.—A little above the middle of the mediastinal surface of each lung, and nearer its posterior than its anterior border, is the root of the lung, by which the lung is united to the heart and the trachea. The root is formed by the bronchus, the pulmonary artery, the two pulmonary veins, the bronchial arteries and veins, the pulmonary plexuses of nerves, lymphatic vessels, bronchial lymph-glands, and areolar tissue, all of which are enveloped by pleura. The roots of the lungs lie opposite the bodies of the fifth, sixth and seventh thoracic vertebrae. That of the right lung lies behind the superior vena cava and part of the right atrium of the heart, and below the azygos vein. That of the left lung is below the aortic arch and in front of the descending aorta. The following relations are common to the two lung-roots, viz.: in front, the phrenic nerve, the pericardiophrenic artery and vein, and the anterior pulmonary plexus; behind, the vagus and posterior pulmonary plexus; below, the pulmonary ligament.

The chief structures composing the root of each lung are arranged in a similar manner from before backwards on both sides, viz.: the upper of the two pulmonary veins in front; the pulmonary artery in the middle; and the bronchus behind, with the bronchial vessels on its posterior aspect. Their arrangement differs from above downwards on the two sides; on the right side their position is—*eparterial* bronchus, pulmonary artery, *hyparterial* bronchus, pulmonary veins; but on the left side their position is—pulmonary artery, bronchus, pulmonary veins. The lower of the two pulmonary veins is situated below the bronchus, at the apex or lowest part of the hilum (figs. 958, 959).

Divisions of the bronchi.—Just as the lungs differ from each other in the number of their lobes, so the bronchi differ in their mode of subdivision.

The *right* bronchus gives off, about 2.5 cm. from the bifurcation of the trachea, a branch for the superior lobe. This branch arises above the level of the pulmonary artery, and is therefore named the *eparterial bronchus*. All the other divisions of the main stem come off below the pulmonary artery, and are consequently termed *hyparterial bronchi*. The first of these is distributed to the middle lobe, and the main tube then passes downwards and backwards into the inferior lobe, giving off in its course a series of large ventral and small dorsal branches. The ventral and dorsal branches arise alternately, and there are usually four of each. The branch to the middle lobe is regarded as the first of the ventral series.

The *left* bronchus passes below the level of the pulmonary artery before it divides, and hence all its branches are *hyparterial*; it may therefore be looked upon as equivalent to that portion of the right bronchus which lies on the distal side of its *eparterial* branch. The first branch of the left bronchus arises about 5 cm. from the bifurcation of the trachea, and is distributed to the superior lobe. The main stem then enters the inferior lobe, where it divides into ventral and dorsal branches similar to those in the right lung. The branch to the superior lobe of the left lung is regarded as the first of the ventral series.

Structure.—The lungs are composed of a serous coat, a subserous areolar tissue, and the pulmonary substance or parenchyma.

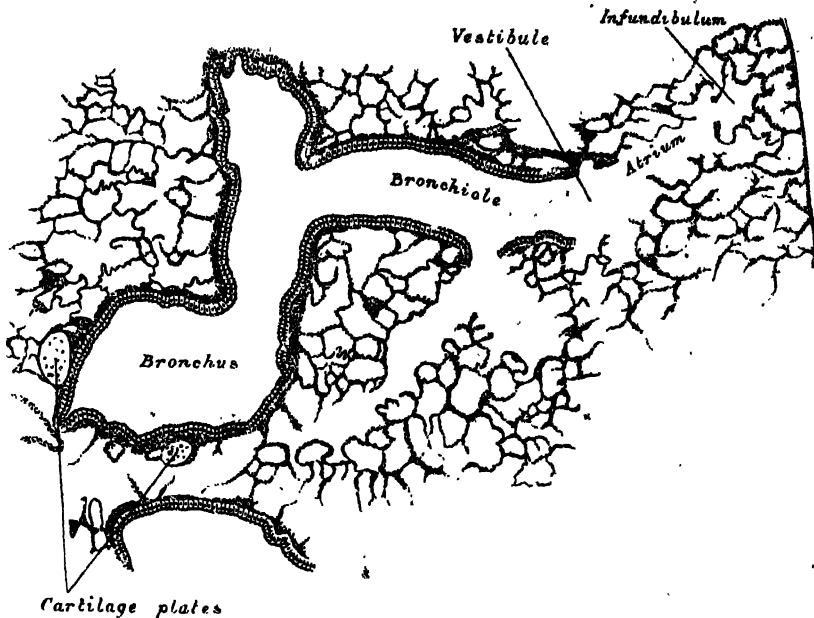
The *serous coat* is the pulmonary pleura (p. 1081); it is thin, transparent, and invests the entire organ as far as the root.

The *subserous areolar tissue* contains a large proportion of elastic fibres; it invests the entire surface of the lung, and extends inwards between the lobules.

The *parenchyma* is composed of lobules which, although closely connected together by interlobular areolar tissue, are quite distinct from one another, and in the *fetus* may be teased asunder without much difficulty. The lobules vary in size; those on the surface are large, of pyramidal form, the bases turned towards the surface; those in the interior smaller, and of various forms. Each lobule is composed of a lobular bronchiole and its terminal air-cells, and of the ramifications of the pulmonary and bronchial vessels, lymphatics, and nerves; all of these structures being connected together by areolar tissue.

The *intrapulmonary bronchi* divide and subdivide throughout the entire organ, the smallest subdivisions constituting the *lobular bronchioles*. The *larger divisions* consist of: (1) an outer coat of fibrous tissue in which are found at intervals irregular plates of hyaline cartilage, most developed at the points of division; (2) internal to the fibrous coat, a layer of circularly disposed smooth muscular fibres, the *bronchial muscle*; and (3) most internally, the *mucous membrane*, lined by columnar ciliated epithelium resting on a basement membrane. The mucous membrane contains numerous elastic fibres running longitudinally, and a certain amount of lymphoid tissue; it is traversed by the

FIG. 960.—A section of the lung of a cat, showing the termination of a bronchus. $\times 50$.



ducts of mucous glands, the acini of which lie in the fibrous coat. The *lobular bronchioles* are about 0.2 mm. in diameter; they differ from the larger tubes in containing no cartilage and in the fact that the ciliated epithelial cells are cubical in shape.

Each bronchiole ends by opening into a wider space known as the *vestibule*, the point of junction of the two being marked by a circular thickening of the bronchial muscle, and by a transition from the ciliated epithelium of the bronchiole to a layer of flattened non-ciliated cells. The vestibule divides into from three to six passages called *atria*. These are lined by flattened non-ciliated epithelium. From each atrium arise two or more *infundibula*, elongated passages, lined by simple squamous epithelium and beset on all sides by hemispherical alveoli or air-cells (fig. 960).

The *alveoli* are lined by a layer of simple squamous epithelium, the cells of which are united at their edges by cement substance. Between the squamous cells are here and there smaller, polygonal, nucleated cells. Outside the epithelial lining is a little delicate connective tissue, containing numerous elastic fibres and a close network of blood-capillaries, and forming a common wall to adjacent alveoli (fig. 961).

The *fetal lung* resembles a gland in that the alveoli have a small lumen and are lined by cubical epithelium (fig. 962). After the first respiration the alveoli become distended, and the epithelium takes on the characters described above.

Vessels and Nerves.—The *pulmonary artery* conveys the venous blood to the lungs; it divides into branches which accompany the bronchial tubes and end in a dense capillary network in the walls of the infundibula and alveoli. The arteries of neighbouring lobules are independent of one another.

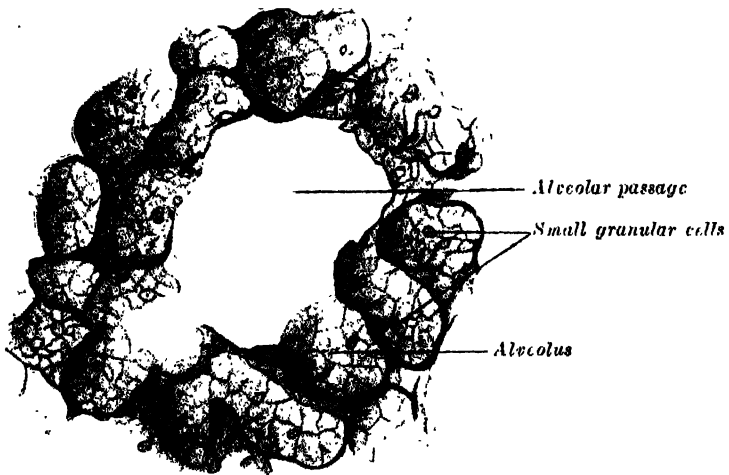
The *pulmonary capillaries* form plexuses which lie immediately beneath the lining epithelium, in the walls and septa of the alveoli and of the infundibula. In the septa

between the alveoli the capillary network forms a single layer, the meshes of which are smaller than the vessels themselves; their walls are also exceedingly thin.

The *pulmonary veins* arise from the pulmonary capillaries, the radicles coalescing into larger branches which run through the substance of the lung, independently of the pulmonary arteries and bronchi. After freely communicating with other branches they form large vessels, which ultimately come into relation with the arteries and bronchial tubes, and accompany them to the hilum of the lung, the artery usually being above, and the vein below, the bronchus. Finally they open into the left atrium of the heart, conveying oxygenated blood to be distributed to all parts of the body by the aorta.

The *bronchial arteries* supply blood for the nutrition of the lung; they are derived from the thoracic aorta or from the upper aortic intercostal arteries, and, accompanying the bronchial tubes, are distributed to the bronchial glands and upon the walls of the larger bronchial tubes and pulmonary vessels. Those supplying the bronchial tubes form, in the muscular coat, a capillary plexus from which branches are given off to form a second plexus in the mucous coat; this plexus communicates with branches of the pulmonary artery, and empties itself into the pulmonary veins. Others are distributed

FIG. 961.—A section of the lung of a kitten. Silver preparation. $\times 350$.



in the interlobular areolar tissue, and end partly in the deep, partly in the superficial, bronchial veins. Lastly, some ramify upon the surface of the lung, beneath the pleura, where they form a capillary network.

The *bronchial veins*, usually two on either side, are formed at the root of the lung, and receive superficial and deep veins corresponding with branches of the bronchial arteries; they do not, however, receive all the blood conveyed by the arteries, as some of it passes into the pulmonary veins. The right bronchial veins end in the azygos vein, the left bronchial veins in the left superior intercostal vein or the accessory hemiazygos vein.

The *lymphatics* of the lungs are described on p. 738.

Nerves.—The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and vagus. The filaments from these plexuses accompany the bronchial tubes, supplying efferent fibres to the bronchial muscle and afferent fibres to the bronchial mucous membrane and to the alveoli of the lung. Small ganglia are found upon these nerves.

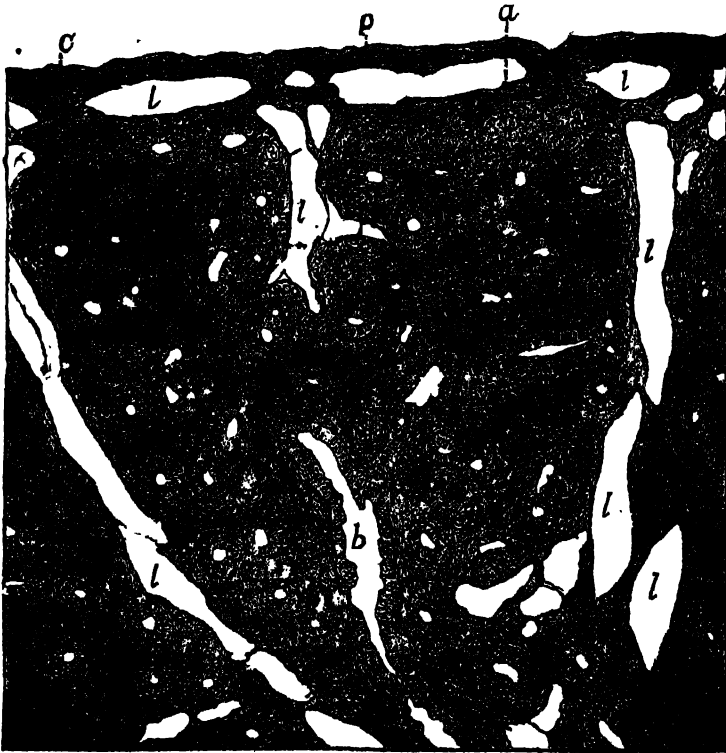
Applied Anatomy.—The lungs may be wounded or torn in three ways: (1) by compression of the chest, without any injury to the ribs; (2) by a fractured rib penetrating the lung; (3) by stabs, gunshot wounds, etc.

The first form, where the lung is ruptured by external compression, without any fracture of the ribs, is very rare, and usually occurs in young children, and affects the root of the lung, i.e. the most fixed part, and thus, implicating the great vessels, is frequently fatal. It would seem *a priori* a most unusual injury, and its exact mode of causation is difficult to interpret.

In the second variety, when the wound in the lung is produced by the penetration of a broken rib, both the costal pleura and pulmonary pleura must necessarily be injured, and consequently the air taken into the wounded alveoli may find its way through these wounds into the cellular tissue of the parietes of the chest, producing *surgical emphysema*. This it may do without collecting in the pleural cavity; the two layers of the pleura are so intimately in contact that the air passes straight through from the wounded lung into the subcutaneous tissue. Emphysema constitutes therefore the most important

sign of injury to the lung in cases of fracture of the ribs. Pneumothorax, or air in the pleural cavity, is much more likely to occur in injuries of the third variety—that is to say, from external wounds, from stabs, gunshot injuries, and such like—in which case air passes either from the wound of the lung or from the external wound into the cavity of the pleura during the respiratory movements. In these cases there is generally no emphysema of the subcutaneous tissue unless the external wound is small and valvular, so that the air is drawn into the wound during inspiration, and then forced into the cellular tissue during expiration because it cannot escape from the external wound. Occasionally in wounds of the parietes of the chest no air finds its way into the cavity of the pleura, because the lung at the time of the accident protrudes through the wound and blocks the opening. This takes place where the wound is large, and constitutes one form of *hernia* of the lung. Another form of *hernia* of the lung occurs, though very rarely, after wounds of the chest-wall, when the wound has healed and the cicatrix subsequently

FIG. 962.—A section of the lung of a pig-embryo, 13 cm. long, showing the glandular character of the developing alveoli. $\times 70$. (J. M. Flint.)



a. Interstitial connective tissue. b. A bronchial tube. c. An alveolus. l. Lymphatic clefts. p. Pleura.

yields from the pressure of the viscus behind. It forms a globular, elastic, crepitating swelling, which enlarges during expiratory efforts, falls in during inspiration, and disappears on holding the breath.

An incision into the lung is occasionally required in cases of abscess the result of pneumonia or the presence of a foreign body, and from an abscess in the liver which has made its way through the Diaphragm into the lung substance, and also in cases of hydatid disease. In these cases there is always risk of hæmorrhage, and it has been recommended that the lung tissue should be penetrated by the actual cautery rather than with the knife. Unless adhesions have formed between the two layers of the pleura, the pleural cavity must necessarily be opened, and there is the further risk of pneumothorax, and possibly of septic infection. It is therefore advisable to suture the lung to the opening in the thoracic wall, and wait for adhesions to form before perforating the lung.

The routine methods of physical examination—inspection, palpation, percussion, and auscultation—are nowhere more important than they are in the diagnosis of disease of the lungs. It is essential, too, that in every case the two sides of the chest should be compared with one another, and that the wide variations that may be met with under normal conditions in different persons and at different ages should be kept in mind when the chest is being examined. On inspection the thorax will be seen to be enlarged and

barrel-shaped in emphysema, in which the volume of the lungs is increased by dilatation of their alveoli, or in an acute attack of asthma, or when a large pleural effusion or mediastinal tumour is present. The chest-wall will be flattened or sunken, on the other hand, over an area of lung that has collapsed or become fibrosed, as often happens in chronic pulmonary tuberculosis. The respiratory movements of the chest-wall will be lessened, or even absent, over a part or the whole of the affected side in such acute disorders as pleurisy, pneumonia, or pleural effusion, or in more chronic disease where the underlying lung is fibrosed, or is crushed to one side by a mediastinal tumour; and by the use of the x-rays a corresponding loss of movement or displacement of the Diaphragm on the affected side can often be observed. Under normal conditions the intercostal spaces are a little depressed; but when a large effusion or new growth fills up one of the pleural cavities they may be obliterated or even bulging on that side.

On *palpation* the hand can be used to verify the eye's impressions as to the degree of movement, on respiration, of any part of the chest-wall. The facility with which the vibrations produced by the voice are conducted from the larynx by the underlying lung to the hand (in the form of *vocal fremitus*) can also be tested. The vocal fremitus is commonly much increased over the consolidated area in pneumonia or in fibrosis of the lung, and much diminished over a pleural effusion when the lung is pushed up by the fluid towards the top of the pleural cavity. It is also diminished, but to a less extent, in emphysema, and in bronchitis when the bronchi are blocked by secretion. In bronchitis the bubbling of the secretion in the tubes can often be felt by a hand placed on the chest-wall as the patient breathes; and in chronic pleurisy the friction of the two roughened pleural surfaces against one another can sometimes be felt in the same way. It must be remembered that the vocal fremitus in front and behind is normally greater at the right apex than the left. This is because the apex of the right lung lies in close contact with the trachea (see fig. 954), while the apex of the left lung is separated from it by the œsophagus and other structures.

On *percussion*, the normal resonance of the pulmonary tissue is found to be increased in emphysema, and in pneumothorax (p. 1034) this hyper-resonance may be still further increased. The resonance is lessened in any condition causing collapse or solidification of the lung-tissue, or when its place is taken by fluid (pleural effusion) or some solid growth (mediastinal tumour). Thus dullness on percussion at the bases of the lungs is common in the hypostatic congestion of the bases seen in heart-failure; dullness at the right base is often due to compression of the lung by enlargement of the liver; some dullness at the apex of a lung is frequently met with in tuberculosis of that part, before the disease has progressed very far. Complete dullness over one side of the chest, back and front alike, except at the apex, is common when a large pleural effusion has taken the lung's place. Von Korányi, Grocco, and others have drawn attention to a triangular patch of dullness along the vertebral column (the paravertebral triangle of dullness) on the unaffected side in pleural effusion; this triangle of dullness is said to be absent in other conditions causing loss of pulmonary resonance on percussion, and is due to shifting over of the contents of the posterior mediastinal cavity towards the sound side. The apex of this triangle is in the middle line at the upper level of the fluid effusion; its base, some 5 cm. to 10 cm. in length, runs horizontally outwards from the middle line at the level where the pulmonary resonance normally comes to an end.

On *auscultation* of the lungs, both in health and disease, the variety of sounds to be heard is very great. It is impossible to give adequate consideration to them here, and for further information reference should be made to the text-books dealing with the subject.*

DIGESTIVE APPARATUS

The apparatus for the digestion of the food consists of the digestive tube and of certain accessory organs.

The **digestive tube**, about 9 metres long, extends from the mouth to the anus, and is lined throughout by mucous membrane. It consists of the following parts: at its commencement is the *mouth*, where provision is made for the mechanical division of the food (*mastication*), and for its admixture with a fluid secreted by the salivary glands (*insalivation*); beyond this are the organs of deglutition, the *pharynx* and the *œsophagus*, which convey the food into the *stomach*, where the first stages of the digestive process take place; the stomach is followed by the *small intestine*, which consists of three parts, the *duodenum*, the *jejunum*, and *ileum*. In the small intestine the process of digestion is completed and the resulting products are absorbed into the blood and lacteal vessels. Finally the small intestine ends in the *large intestine*, which is made up of the *cæcum*, the *colon*, the *rectum*, and the *anal canal*, the last terminating on the surface of the body at the *anus*.

* See especially *Auscultation and Percussion*, by Samuel Gee. Edit. 5, 1906. Smith, Elder & Co.

The **accessory organs** are the *teeth*, for purposes of mastication; the three pairs of *salivary glands*—the *parotid*, *submaxillary*, and *sublingual*—the secretion from which mixes with the food in the mouth and acts chemically on one of its constituents; the *liver* and the *pancreas*, two large glands in the abdomen, the secretions of which, in addition to that of numerous minute glands in the walls of the alimentary canal, take part in the process of digestion.

THE MOUTH CAVITY (CAVUM ORIS)

The **cavity of the mouth** is placed at the commencement of the digestive tube (fig. 963); it consists of an outer, smaller portion, the *vestibule*, and an inner, larger part, the *mouth cavity proper*.

The *vestibule of the mouth* is a slit-like space, bounded externally by the lips and cheeks; internally by the gums and teeth. It communicates with the surface of the body by the *rima* or *orifice of the mouth*. Above and below, it is limited by the reflection of the mucous membrane from the lips and cheeks to the gums covering the upper and lower alveolar arch respectively. It receives the secretion from the parotid salivary glands, and communicates, when the jaws are closed, with the mouth cavity proper by an aperture on either side behind, the wisdom teeth, and by narrow clefts between opposing teeth.

The *mouth cavity proper* (fig. 984) is bounded laterally and in front by the alveolar arches with their contained teeth; behind, it communicates with the pharynx by a constricted aperture termed the *isthmus faucium*. Its roof consists of the hard and soft palates, while the greater part of the floor is formed by the tongue, the remainder by the reflection of the mucous membrane from the sides and under surface of the tongue to the gum lining the inner surface of the mandible. It receives the secretion from the submaxillary and sublingual salivary glands.

The *mucous membrane* lining the mouth is continuous with the skin at the free margins of the lips, and with the mucous lining of the pharynx behind; it is of a rose-pink tinge during life, and very thick where it overlies the hard parts bounding the cavity. It is covered by stratified squamous epithelium.

The *lymphatics* of the mouth are described on p. 717.

The **lips** (*labia oris*), the two fleshy folds which surround the rima or orifice of the mouth, are formed externally of skin and internally of mucous membrane, between which are found the Orbicularis oris muscle, the labial vessels, some nerves, areolar tissue, and fat, and numerous small labial glands. On the middle part of the outer surface of the upper lip is a shallow vertical groove named the *philtrum* which ends below in a slight prominence and is limited on either side by a ridge. The inner surface of each lip is connected in the middle line to the corresponding gum by a fold of mucous membrane, the *frenulum*—that of the upper lip being the larger.

The *labial glands* are situated between the mucous membrane and the Orbicularis oris, round the orifice of the mouth. They are circular in form, and about the size of small peas; their ducts open upon the mucous membrane. In structure they resemble the salivary glands.

The **cheeks** (*buccæ*) form the sides of the face, and are continuous in front with the lips. They are composed externally of skin, and internally of mucous membrane; between these are a muscular stratum, and a large quantity of fat, together with areolar tissue, vessels, nerves, and buccal glands.

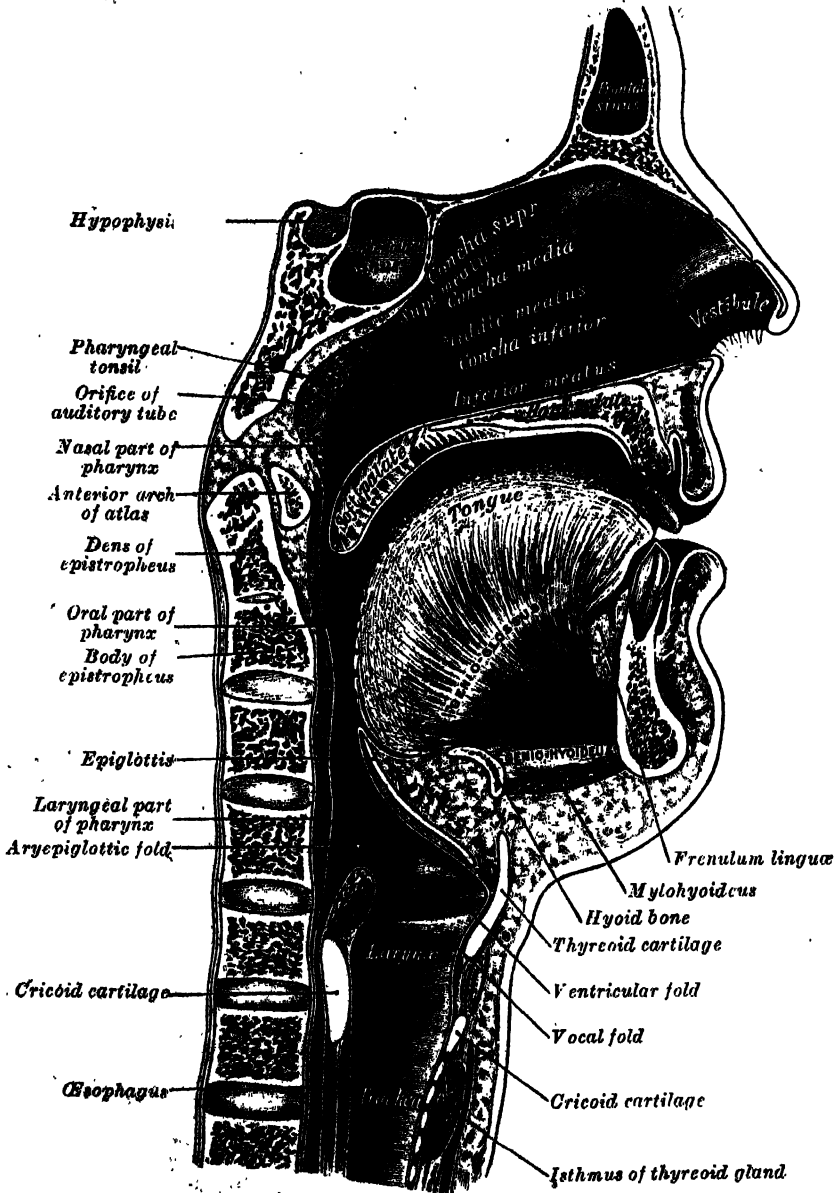
The *mucous membrane* lining the cheek is reflected above and below upon the gums, and is continuous behind with the lining membrane of the soft palate. Opposite the second upper molar tooth is a papilla, on the summit of which the parotid duct opens. The principal muscle of the cheek is the Buccinator; but others enter into its formation, viz. the Zygomaticus, Bisorius, and Platysma.

The *buccal glands* are placed between the mucous membrane and the Buccinator muscle; their structure is similar to that of the labial glands. Four or five, larger than the rest, and placed between the Masseter and Buccinator muscles around the distal extremity of the parotid duct, are called *molar glands*; their ducts open in the mouth opposite the last molar tooth.

The *lymphatics* of the cheeks and lips are described on p. 716.

The gums (gingivæ) are composed of dense fibrous tissue, closely connected to the periosteum of the alveolar processes, and surrounding the necks of the teeth. The gums are covered by smooth and vascular mucous membrane, which is remarkable for its limited sensibility. Around the necks of the teeth this

FIG. 988.—A sagittal section of the nose, mouth, pharynx, and larynx.



membrane presents numerous fine papillæ, and is reflected into the alveoli, where it is continuous with the periosteal membrane lining these cavities.

Applied Anatomy.—The gums are occasionally the seat of considerable hypertrophy, forming a lobulated vascular fold growing up in front of and behind the teeth, so as almost to bury them. They may also become swollen and congested, bleeding freely, and often becoming ulcerated. The condition is known as *spongy gums*, and may occur in scurvy, leucæmia, and dyspepsia, in ill-fed tuberculous children, and from the administration of mercury; the gums are very tender, mastication is painful, and there is often considerable labor. The dental margin of the gum presents a finely stippled blue or blue-black

line in cases of *lead poisoning*, due to the local deposit of black lead sulphide. In cases of *bismuth poisoning*, such as may occur after the too generous use of insoluble bismuth salts in the surgical treatment of gunshot wounds, a very similar but more diffuse black line due to the local deposit of black sulphide of bismuth may appear, together with patches of minute black dots about other parts of the mucous membrane of the mouth. The collection of tartar, which consists of the secretion from the gums mixed with fragments of food and salivary salts, may give rise to a condition known as *pyorrhœa alveolaris*, which is an inflammatory condition of the gums, followed by the gradual absorption of the alveolus and the falling out of the teeth. Fibrous tumours (epulis), myeloid growths, and epitheliomata are met with in the gums.

The **palate** forms the roof of the mouth: it consists of two portions, the hard palate in front, the soft palate behind.

The **hard palate** (fig. 971) is formed by the palatine processes of the maxillæ and the horizontal parts of the palatine bones; it is bounded in front and at the sides by the alveolar arches and gums; behind, it is continuous with the soft palate. It is covered by a dense tissue, formed by the periosteum and mucous membrane, which are intimately connected. Along the middle line is a linear raphe, which ends anteriorly in a small papilla corresponding with the incisive canal. On either side and in front of the raphe the mucous membrane is thick, pale in colour, and corrugated; behind, it is thin, smooth, and of a deeper colour: it is covered with stratified squamous epithelium, and furnished with numerous palatine glands which lie between the mucous membrane and the periosteum.

The **soft palate** (fig. 984) is a movable fold, suspended from the posterior border of the hard palate, and forming an incomplete septum between the mouth and pharynx. It consists of a fold of mucous membrane enclosing muscular fibres, an aponeurosis, vessels, nerves, adenoid tissue, and mucous glands. When occupying its usual position (i.e. relaxed and pendent) its anterior surface is concave, and marked by a median raphe. Its posterior surface is convex, and continuous with the floor of the nasal cavities. Its superior border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx. Its inferior border is free. The lower portion of the soft palate hangs like a curtain between the mouth and the pharynx, and is termed the *palatine velum*.

Hanging from the middle of its lower border is a small, conical, pendulous process, the *palatine uvula*; and arching lateralwards and downwards from the base of the uvula on either side are two curved folds of mucous membrane, containing muscular fibres, called the *arches* or *pillars of the fauces* (p. 1072).

The *mucous membrane of the soft palate* is thin, and covered with stratified squamous epithelium, excepting near the pharyngeal ostium of the auditory tube, where it is columnar and ciliated. Beneath the mucous membrane on the oral surface of the soft palate is a considerable amount of adenoid tissue. The palatine glands form a continuous layer on its posterior surface and round the uvula.

Vessels and Nerves.—The *arteries* supplying the palate are the ascending palatine branch of the external maxillary artery, the descending palatine branch of the internal maxillary artery, and the palatine branch of the ascending pharyngeal artery. The *veins* end chiefly in the pterygoid and tonsillar plexuses. The *lymphatic vessels* pass to the deep cervical lymph-glands. The *sensory nerves* are derived from the palatine, nasopalatine and glossopharyngeal nerves.

Applied Anatomy.—The occurrence of a congenital cleft in the palate has been already referred to as a defect in development (p. 264). After the operation for the closure of a cleft in the palate, the palatine muscles, especially the Tensor and Levator veli palatini, have a tendency to retard the healing process by active traction upon the line of suture. To obviate this, it is necessary to divide them. This is best done by making longitudinal incisions, on either side, parallel to the cleft and just medial to the pterygoid hamulus, in such a position as to avoid the descending palatine artery. Acquired perforations of the palate are almost invariably the result of the breaking down of syphilitic gummata. The ensuing ulceration may continue until practically the whole palate, both hard and soft, has been destroyed. Tumours of the palate, both innocent and malignant, are occasionally seen.

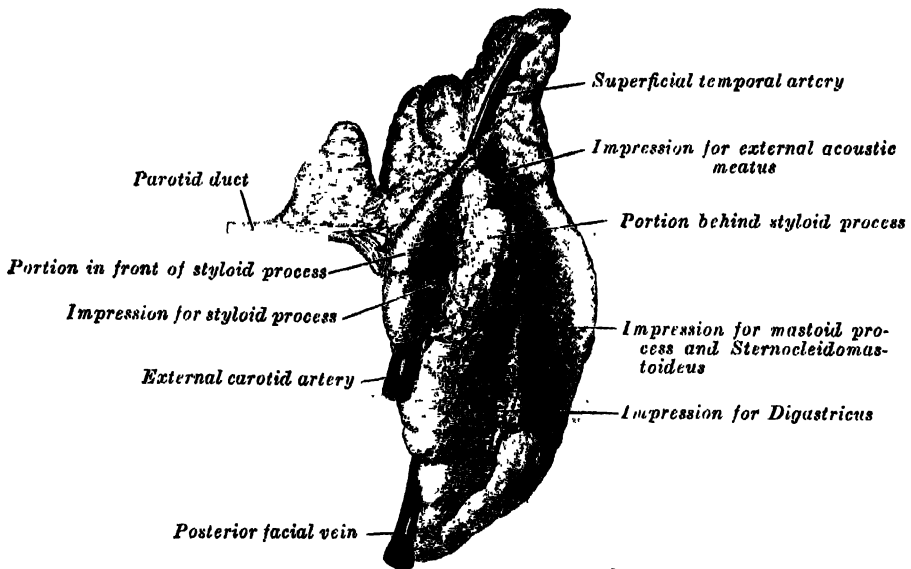
Paralysis of the soft palate often occurs after diphtheria. It gives rise to a change in the voice, which becomes nasal, and to the regurgitation of fluids down the nose when their swallowing is attempted. On inspection, the palate is seen to hang flaccid and motionless when phonation or deglutition is attempted; it is also anæsthetic.

THE SALIVARY GLANDS (fig. 966)

Three pairs of salivary glands communicate with the mouth, and pour their secretion into its cavity: they are the parotid, submaxillary, and sublingual.

Parotid gland.—The parotid gland (figs. 964, 965), the largest of the three, has an average weight of about 25 gm. It lies upon the side of the face, immediately below and in front of the external ear. The main portion of the gland is superficial, somewhat flattened and quadrilateral in form, and is placed between the ramus of the mandible in front and the mastoid process and Sternocleidomastoideus behind, overlapping, however, both boundaries. Above, it is broad and reaches nearly to the zygomatic arch; below, it tapers

FIG. 964.—The right parotid gland. Posterior and deep aspects.



somewhat to about the level of a line joining the tip of the mastoid process to the angle of the mandible. The remainder of the gland is irregularly wedge-shaped and extends deeply inwards towards the pharyngeal wall.

The gland is enclosed within a capsule continuous with the fascia colli (deep cervical fascia); the part covering the superficial surface is dense, closely adherent to the gland, and attached to the zygomatic arch; a portion of the fascia, attached to the styloid process and the angle of the mandible, is thickened to form the stylomandibular ligament which intervenes between the parotid and submaxillary glands.

The *anterior surface* of the gland is grooved, being moulded on the posterior border of the ramus of the mandible, and on the posterior borders of the Pterygoideus internus and Masseter. The inner lip of the groove dips, for a short distance, between the two Pterygoid muscles; the outer lip extends for some distance over the superficial surface of the Masseter, and a small portion of it immediately below the zygomatic arch is usually detached, and is named the *accessory part* of the gland.

The *posterior surface* is grooved longitudinally and abuts against the external acoustic meatus, the mastoid process, and the anterior border of the Sternocleidomastoideus.

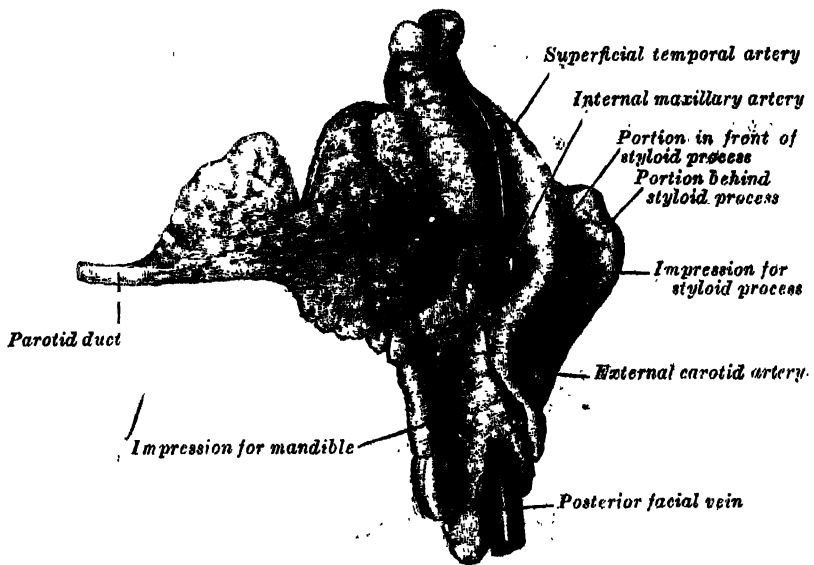
The *superficial surface*, slightly lobulated, is covered by the skin, the superficial fascia containing the facial branches of the great auricular nerve and some small lymph-glands, and by the fascia which forms the capsule of the gland.

The *deep surface* extends inwards by means of two processes, one of which lies on the Digastricus, styloid process, and the styloid group of muscles, and projects under the mastoid process and Sternocleidomastoideus; the other is situated in front of the styloid process, and sometimes passes into the posterior part of the mandibular fossa behind the temporomandibular joint. The deep surface is in contact with the internal and external carotid arteries, the internal jugular vein, and the vagus and glossopharyngeal nerves.

The gland is separated from the pharyngeal wall by some loose connective tissue.

Structures within the gland.—The external carotid artery lies at first on the deep surface, and then in the substance of the gland. The artery gives off its posterior auricular branch which emerges from the gland behind; the artery then divides into the internal maxillary and superficial temporal arteries; the former runs forwards deep to the neck of the mandible; the latter runs

FIG. 965.—The right parotid gland. Deep and anterior aspects.



upwards across the zygomatic arch and gives off its transverse facial branch which emerges from the front of the gland. Superficial to the arteries are the superficial temporal and internal maxillary veins, uniting to form the posterior facial vein; in the lower part of the gland this vein splits into anterior and posterior divisions. The anterior division emerges from the gland and unites with the anterior facial vein to form the common facial vein; the posterior unites in the gland with the posterior auricular vein to form the external jugular vein. On a still more superficial plane is the facial nerve, the branches of which emerge from the borders of the gland. Branches of the great auricular nerve pierce the gland to join the facial nerve, and the cutaneous part of the auriculotemporal nerve issues from the upper part of the gland.

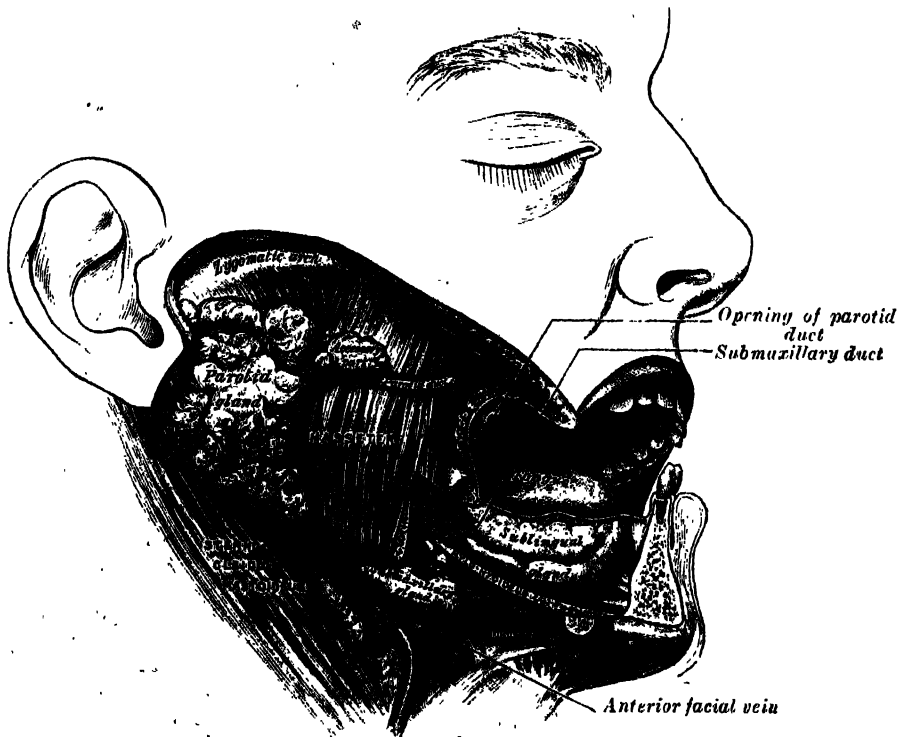
The parotid duct (Stensen's duct) (fig. 966) is about 5 cm. long. It begins by numerous branches from the anterior part of the gland, crosses the Masseter, and at the anterior border of this muscle turns inwards nearly at a right angle, passes through the corpus adiposum of the cheek and pierces the Buccinator; it then runs for a short distance obliquely forwards between the Buccinator and mucous membrane of the mouth, and opens upon a small papilla on the oral surface of the cheek opposite the second upper molar tooth. While crossing the Masseter it receives the duct of the accessory portion; in this position it lies between the branches of the facial nerve; the accessory part of the gland and the transverse facial artery are above it.

Structure.—The wall of the parotid duct is of considerable thickness, and consists of a thick external fibrous coat which contains unstriated muscular fibres, and an internal mucous coat which is lined with short columnar epithelium. Its canal is about the size of a crow-quill, but at its orifice on the oral surface of the cheek its lumen is greatly reduced in size.

Vessels and Nerves.—The *arteries* supplying the parotid gland are derived from the external carotid, and from the branches given off by that vessel in or near the gland. The *veins* empty themselves into the external jugular, through some of its tributaries. The *lymphatics* end in the superficial and deep cervical lymph-glands, passing in their course through two or three lymph-glands, on the surface and in the substance of the parotid. The *nerves* are derived from the facial, auriculotemporal and great auricular nerves and from the plexus of the sympathetic on the external carotid artery. It is probable that the branch from the auriculotemporal nerve is derived from the glossopharyngeal through the otic ganglion; at all events, in some of the lower animals this has been proved experimentally to be the case.

Submaxillary gland.—The submaxillary gland (fig. 966) is irregular in form and about the size of a walnut. A considerable part of it is situated in the

FIG. 966.—A dissection showing the salivary glands of the right side.



submaxillary triangle, reaching forwards to the anterior belly of the Digastricus and backwards to the stylomandibular ligament, which intervenes between it and the parotid gland. Above, it extends under cover of the body of the mandible; below, it usually overlaps the intermediate tendon of the Digastricus and the insertion of the Stylohyoideus, while from its deep surface a tongue-like *deep process* extends forwards above the Mylohyoideus muscle.

Its *superficial surface* consists of an upper and a lower part. The *upper part* is directed outwards, and lies partly against the submaxillary depression on the inner surface of the body of the mandible, and partly on the Pterygoideus internus. The *lower part* is directed downwards and outwards, and is covered by the skin, superficial fascia, Platysma, and deep cervical fascia; it is crossed by the anterior facial vein and by filaments of the facial nerve; in contact with it, near the mandible, are the submaxillary lymph-glands.

The *deep surface* is in relation with the Mylohyoideus, Hyoglossus, Styloglossus, Stylohyoideus, and posterior belly of the Digastricus; in contact with it are the mylohyoid nerve and the mylohyoid and submental vessels.

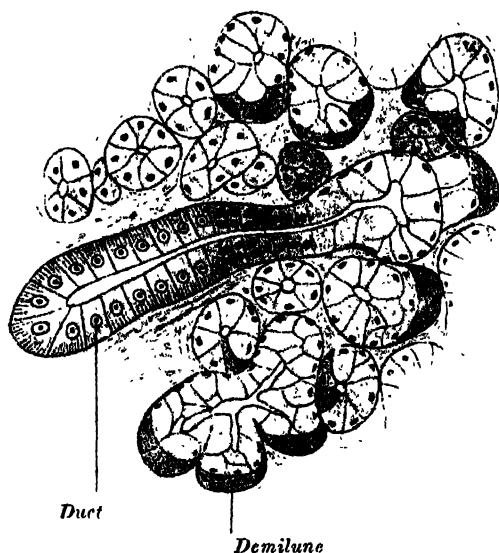
The external maxillary artery is imbedded in a groove in the posterior border of the gland.

The *deep process* of the gland extends forwards as far as the posterior end of the sublingual gland, and lies between the Mylohyoideus below and externally and the Hyoglossus and Styloglossus internally; above it are the lingual nerve and submaxillary ganglion; below it, the hypoglossal nerve and its vena comitans.

The submaxillary duct (Wharton's duct) is about 5 cm. long, and its wall is much thinner than that of the parotid duct. It begins by numerous branches from the deep surface of the gland, and runs forwards between the Mylohyoideus and the Hyoglossus, and then between the sublingual gland and the Genioglossus, and opens by a narrow orifice on the summit of a small papilla, at the side of the frenulum linguæ. On the Hyoglossus it lies between the lingual and hypoglossal nerves, but at the anterior border of the muscle it is crossed laterally by the lingual nerve; the terminal branches of the lingual nerve ascend on its medial side.

Vessels and Nerves.—The *arteries* supplying the submaxillary gland are branches of the external maxillary and lingual arteries. Its *veins* follow the course of the arteries. The *nerves* are derived from the submaxillary ganglion, through which it receives filaments from the chorda tympani of the facial nerve, the lingual branch of the mandibular nerve and the sympathetic.

FIG. 967.—Section of the submaxillary gland of a kitten. Duct semidiagrammatic. $\times 200$.



In the dog and cat the submaxillary gland receives its nerve-supply through Langley's ganglion (p. 1053).

Sublingual gland.—The sublingual gland (fig. 966) is the smallest of the three glands. It is situated beneath the mucous membrane of the floor of the mouth, at the side of the frenulum linguæ, in contact with the sublingual depression on the inner surface of the mandible, close to the symphysis. It is narrow, flattened, shaped somewhat like an almond, and weighs between 3 and 4 gms. It is in relation, *above*, with the mucous membrane; *below*, with the Mylohyoideus; *in front*, with its fellow of the opposite side; *behind*, with the deep part of the submaxillary gland; *later-*

ally, with the mandible; and *medially*, with the Genioglossus, from which it is separated by the lingual nerve and the submaxillary duct. Its excretory ducts are from eight to twenty in number. Of the *smaller sublingual ducts* (ducts of Rivinus), some join the submaxillary duct; others open separately into the mouth, on the elevated crest of mucous membrane (*plica sublingualis*), caused by the projection of the gland, on either side of the frenulum linguæ. One or more join to form the *larger sublingual duct* (duct of Bartholin), which opens with or near to the submaxillary duct.

Vessels and Nerves.—The sublingual gland is supplied with blood from the sublingual and submental arteries. Its nerves are derived from the lingual and chorda tympani nerves, and from the sympathetic.

In the dog and cat the sublingual gland receives its nerve-supply through the submaxillary ganglion.

Structure of the salivary glands.—The salivary glands are compound racemose glands, consisting of numerous lobes, which are made up of lobules, connected together by dense areolar tissue, vessels, and ducts. Each lobule consists of the ramifications of

a single duct, the branches ending in dilated ends or alveoli on which the capillaries are distributed. The alveoli are enclosed by a basement membrane, which is continuous with the membrana propria of the duct and consists of a network of branched and flattened nucleated cells.

The alveoli of the salivary glands are of two kinds, which differ in the size and appearance of their secreting cells, and in the nature of their secretion. (1) The mucous variety secretes a viscid fluid, which contains mucin; (2) the serous variety secretes a thinner and more watery fluid. The sublingual gland consists of mucous, and the parotid gland of serous, alveoli. The submaxillary gland contains both mucous and serous alveoli (fig. 969).

The cells in the *mucous alveoli* are columnar in shape (fig. 967). In the fresh condition they contain large granules of mucinogen. In hardened preparations a delicate protoplasmic network is seen, and the cells are clear and transparent. The nucleus is usually situated near the basement membrane, and is flattened.

In some alveoli peculiar crescentic bodies are seen between the cells and the membrana propria. They are termed the *crescents of Gianuzzi*, or the *demilunes of Heidenhain* (fig. 967), and are composed of polyhedral granular cells. Fine canaliculi pass between the mucus-secreting cells to reach the demilunes and even penetrate the cells forming these structures.

In the *serous alveoli* the cells almost completely fill the cavity in the resting condition of the gland, so that there is hardly any lumen perceptible: they contain secretory granules imbedded in a closely reticulated protoplasm (fig. 968). The cells are more cubical than those of the mucous type; the nucleus of each is spherical and placed near the centre of the cell, and the granules are smaller.

Both mucous and serous cells vary in appearance according to whether the gland is in a resting condition or has been recently active. In the former case the cells are large and contain many secretory granules; in the latter case the cells are shrunken and contain few granules, chiefly collected at the inner ends of the cells. The granules are best seen in fresh preparations.

The ducts are lined at their origins by epithelium which differs little from the pavement form. As the ducts enlarge, the epithelial cells change to the columnar type, and the part of the cell next the basement membrane is finely striated.

The lobules of the salivary glands are richly supplied with blood-vessels, which form a dense network in the intervalveolar spaces. Fine plexuses of nerves are also found in the interlobular tissue. The

nerve-fibrils pierce the basement membrane of the alveoli, and end in branched varicose filaments between the secreting cells. In the hilum of the submaxillary gland there is a collection of nerve-cells termed *Langley's ganglion*.

Accessory glands.—Besides the salivary glands proper, numerous other glands are found in the mouth. Some of these occur in the tongue (p. 1070); others lie around and in the palatine tonsil between its crypts, and large numbers are present in the soft palate, the lips and cheeks. These glands are of the same structure as the larger salivary glands, and are of the mucous or mixed type.

FIG. 968.—Section of the parotid gland of a cat. $\times 200$.

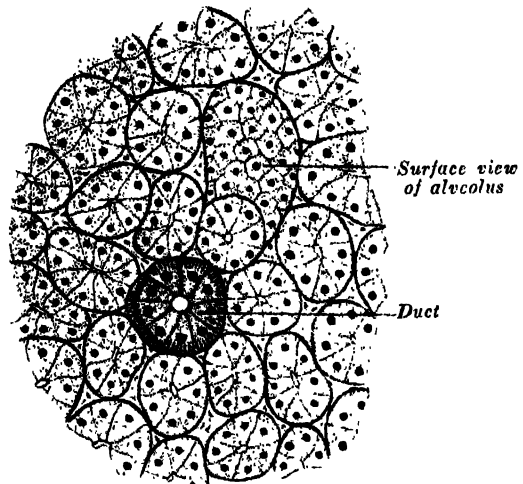
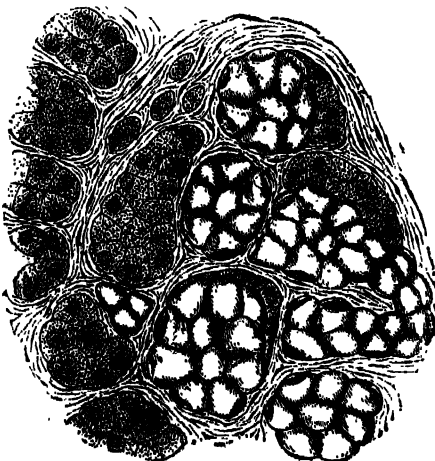


FIG. 969.—A section of a human submaxillary gland. (R. Heidenhain.)



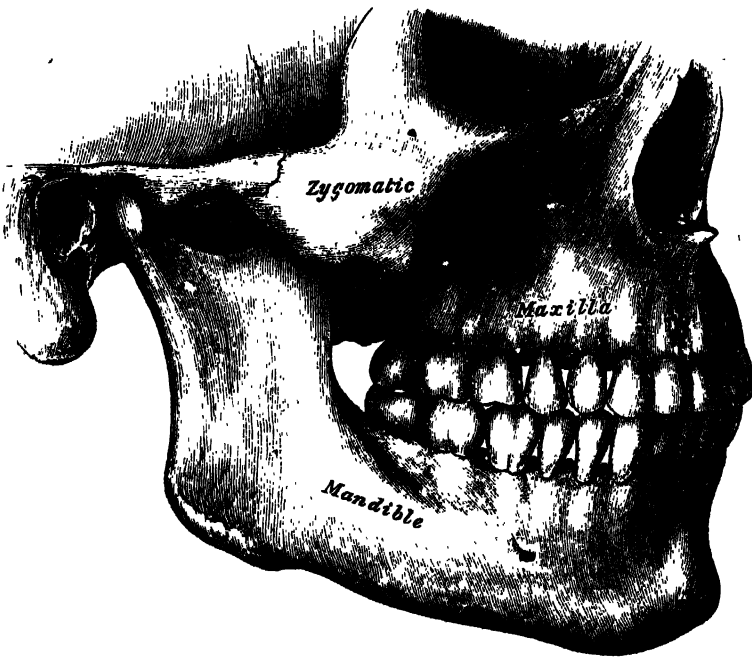
To the right of the figure is a group of mucous alveoli, to the left a group of serous alveoli.

Applied Anatomy.—The parotid glands, and much less often the other salivary glands, are liable to an acute infectious inflammation, known in the case of the parotid as *mumps*. The affected glands swell up, becoming tense, tender, and painful; much pain is felt when swallowing or mastication is attempted, and salivation may or may not occur. The inflammation goes down after a few days; suppuration in the affected glands is very rare.

THE TEETH (DENTES) (figs. 970 to 972)

Man is provided with two sets of teeth, which make their appearance at different periods of life. Those of the first set are temporary and appear during the first and second years; they are called the *deciduous* or *milk* teeth.

FIG. 970.—A side view of the teeth and jaws.



Those of the second set begin to replace the deciduous set about the sixth year; they are all established by the twenty-fifth year, and, since they may continue until old age, are named the *permanent* teeth.

The *deciduous teeth* are twenty in number: four incisors, two canines, and four molars in each jaw.

The *permanent teeth* are thirty-two in number: four incisors, two canines, four premolars, and six molars in each jaw.

The dental formulæ may be represented as follows:

Deciduous Teeth.

	mol.	can.	in.	in.	can.	mol.	
Upper jaw	2	1	2	2	1	2	Total 20
Lower jaw	2	1	2	2	1	2	

Permanent Teeth.

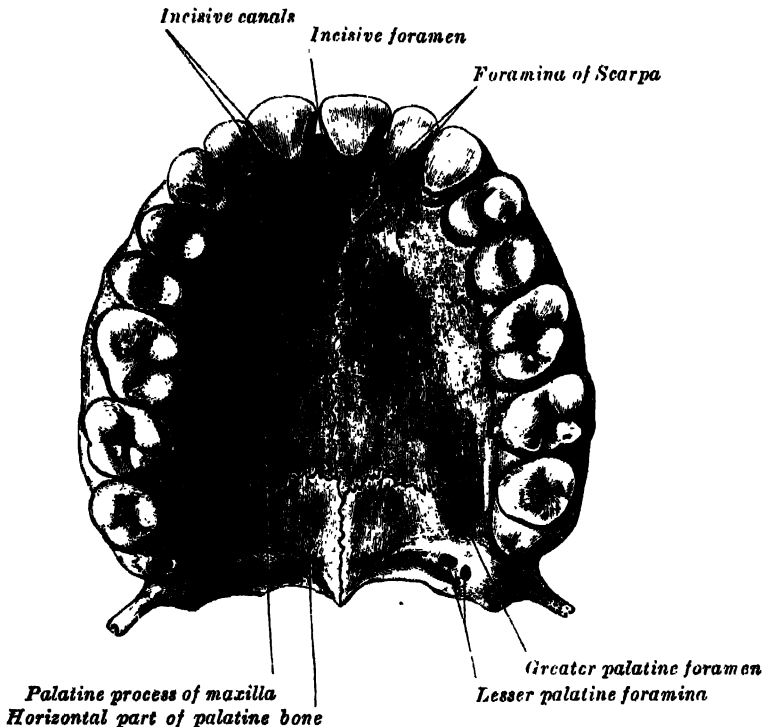
	mol.	premol.	can.	in.	in.	can.	premol.	mol.	
Upper jaw	3	2	1	2	2	1	2	3	Total 32
Lower jaw	3	2	1	2	2	1	2	3	

General characteristics.—Each tooth consists of three portions: the *crown*, projecting beyond the gum; the *root*, imbedded in the alveolus; and the *neck*, the constricted portion between the crown and the root.

The roots of the teeth are firmly implanted in the alveoli of the maxilla and mandible. Each alveolus is lined by periosteum which invests the tooth as far as its neck, and is continuous above with the fibrous tissue of the gums.

In consequence of the curve of the dental arch, terms such as anterior and posterior, if applied to the teeth, would be misleading and confusing. Special terms are therefore used to indicate the different surfaces of a tooth: the surface directed towards the lips or cheek is known as the *labial* or *buccal* surface; that directed towards the tongue is described as the *lingual* surface; those surfaces which touch neighbouring teeth are termed *surfaces of contact*. In the

FIG. 971.—The permanent teeth of the upper dental arch. Seen from below.



case of the incisor and canine teeth the surfaces of contact are medial and lateral; in the premolar and molar teeth they are anterior and posterior.

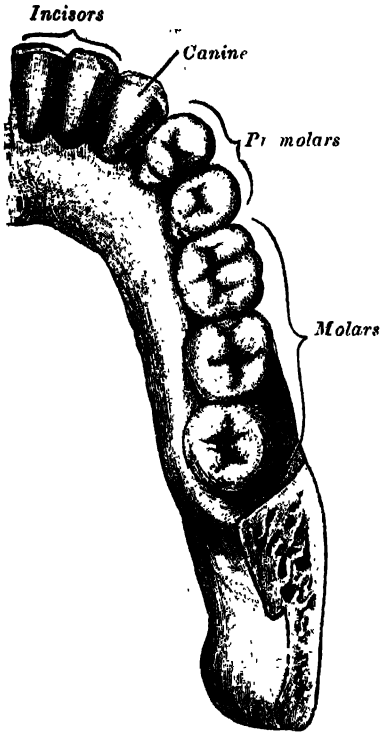
The superior dental arch is larger than the inferior, so that in the normal condition the teeth of the maxilla slightly overlap those of the mandible both in front and at the sides. Since the upper central incisors are wider than the lower, the other teeth in the upper arch are thrown somewhat distalwards, and the two sets do not quite correspond to each other when the mouth is closed. Thus the upper canine tooth rests partly on the lower canine and partly on the first premolar, and the cusps of the upper molar teeth lie behind the corresponding cusps of the lower molar teeth. The dental arches, however, end at nearly the same points behind because the upper molars, especially the third molars, are smaller than the lower.

PERMANENT TEETH (figs. 970 to 973)

The incisive teeth, or incisors, are so named because they present sharp cutting edges, adapted for biting the food. They are eight in number, and form the four front teeth in each dental arch.

The *crown* of each is directed vertically, and is chisel-shaped, being bevelled so as to present a sharp horizontal cutting edge, which, before being subjected

FIG. 972.—The permanent teeth of the right half of the lower dental arch. From above.



to attrition, presents three small prominent points separated by two notches. It is convex on its labial surface; concave on its lingual surface, where, in the teeth of the upper arch, it is frequently marked by an inverted V-shaped eminence, situated near the gum. This is known as the *basal ridge* or *cingulum*. The *neck* is constricted. The *root* is long, single, conical, transversely flattened, thicker in front than behind, and slightly grooved on either side in the longitudinal direction.

The *upper incisors* are larger and stronger than the lower, and are directed obliquely downwards and forwards. They overlap the lower incisors and their free edges are consequently bevelled at the expense of their lingual surfaces. Their roots are conical and nearly cylindrical. The central upper incisors are larger than the lateral.

The *lower incisors* are smaller than the upper. They are placed vertically and are somewhat bevelled in front, where they have been worn down by contact with the overlapping edges of the upper teeth. Their roots are flattened at the sides. The central lower incisors are smaller than the lateral, and are the least of all the incisors.

The *canine teeth* (cuspid) are four in number, two in the upper, and two in the lower arch, one being placed lateral to each

lateral incisor. They are larger and stronger than the incisors, and their roots sink deeply into the bones and cause well-marked prominences upon their surfaces.

FIG. 973.—Permanent teeth. Right side. (Burchard.)



The *crown* of each is large and conical, very convex on its labial surface, a little hollowed and uneven on its lingual surface, and tapering to a blunted point or cusp, which projects beyond the level of the other teeth. The *root*

is single, but longer and thicker than that of the incisors; it is conical in form, compressed laterally, and marked by a slight groove on either side.

The *upper canine teeth* (popularly called *eye-teeth*) are larger and longer than the lower, and usually present a distinct basal ridge.

The *lower canine teeth* are placed nearer the middle line than the upper so that their summits correspond to the intervals between the upper canines and the lateral incisors. The roots of the lower canines are occasionally double.

The *premolars* or *bicuspid teeth* are eight in number, four in each arch. They are situated laterally to and behind the canine teeth, and are smaller and shorter than these.

The *crown* of each is compressed from before backwards, and surmounted by two pyramidal eminences or cusps, a labial and a lingual, separated by a groove. Of the two cusps the labial is the larger and more prominent. The *neck* is oval. The *root* is generally single, but presents in front and behind a deep groove, which indicates a tendency in the root to become double.

The *upper premolars* are larger, and show a greater tendency to the division of their roots than the lower; this is especially the case in the first upper premolar. The roots of the *lower premolars* are nearly cylindrical.

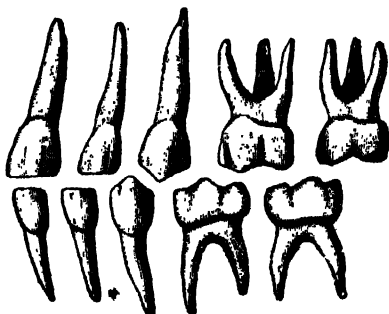
The *molar teeth* are the largest of the permanent set, and their broad crowns are adapted for grinding the food. They are twelve in number, six in each arch, three being placed posterior to each of the second premolars.

The *crown* of each is nearly cubical in form, convex on its buccal and lingual surfaces, flattened on its surfaces of contact; it is surmounted by four or five tubercles, or cusps, separated from each other by a crucial depression; hence the molars are sometimes termed *multicuspids*. The *neck* is distinct, large, and rounded.

Upper molars.—As a rule the first of the upper molars is the largest, and the third the smallest. The crown of the first has usually four tubercles; that of the second, three or four; that of the third, three. Each upper molar has three roots, and of these two are buccal, and nearly parallel to one another; the third is lingual and diverges from the others as it runs upwards. The roots of the third molar (*dens serotinus* or *wisdom-tooth*) are more or less fused together.

Lower molars.—The lower molars are larger than the upper. On the crown of the first there are usually five tubercles; on the crowns of the second and third, four or five. Each lower molar has two roots, an anterior and a posterior, which are curved backwards; both roots are grooved longitudinally, indicating a tendency to division. The two roots of the third molar (*dens serotinus* or *wisdom-tooth*) are more or less united.

FIG. 974.—The deciduous teeth.
Left side.



DECIDUOUS TEETH (fig. 974)

The deciduous or milk teeth resemble in form the teeth which bear the same names in the permanent set; they are, however, smaller and their necks are more constricted. The second molar is the largest of the deciduous teeth. The first upper molar has three cusps, the second has four. The first lower molar has four cusps; the second has five. The roots of the deciduous molars are smaller than those of the permanent molars; they are also more divergent, owing to the fact that the crowns of the permanent molars are lodged between them.

STRUCTURE OF THE TEETH

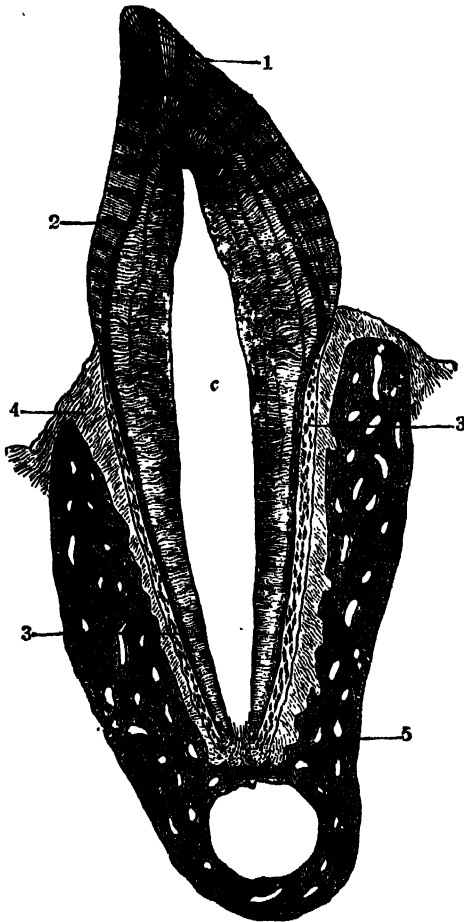
On making a vertical section of a tooth (fig. 975), a cavity is seen in the crown and in the centre of each root; it opens by a minute orifice at the extremity of the latter. This is called the *pulp cavity*, and contains the *dental pulp*, a loose connective tissue richly supplied with vessels and nerves which enter the cavity through the small aperture at the point of each root. Some of the cells of the pulp are arranged as a layer on the wall

of the pulp cavity; they are named *odontoblasts*, and during the development of the tooth are columnar in shape, but after the dentine is fully formed they become flattened. Each sends a fine process into a canaliculus in the dentine.

The solid portion of the tooth consists of (1) the *ivory* or *dentine*, which forms the bulk of the tooth; (2) the *enamel*, which covers the exposed part of the crown; and (3) a thin layer of bone, the *cement* or *crusta petrosa*, which is disposed on the surface of the root.

The *dentine* (*substantia eburnea*) (fig. 978) is a modification of osseous tissue, from which it differs, however, in structure. On microscopic examination it is seen to consist

FIG. 975.—A vertical section of a tooth *in situ*.
×15.



[c is placed in the pulp cavity, opposite the neck of the tooth; the part above it is the crown, that below is the root. 1. Enamel with radial and concentric markings 2. Dentine with tubules and incremental lines. 3. Cement or crusta petrosa, with bone-cells. 4. Dental perlosteum. 5. Mandible.

FIG. 976.—A vertical section of a molar tooth.

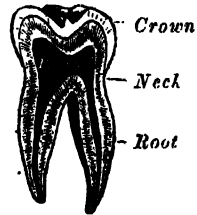
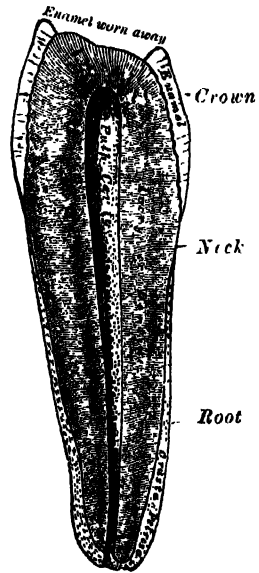


FIG. 977.—A vertical section of a premolar tooth. (Magnified.)



of a number of minute wavy and branching tubes, the *dental canaliculi*, imbedded in a dense homogeneous substance, the *matrix*.

The *dental canaliculi* (fig. 978) are placed parallel with one another, and open at their inner ends into the pulp cavity. In their course to the periphery they present two or three curves, and are twisted on themselves in a spiral direction. These canaliculi vary in direction: thus in a tooth of the mandible they are vertical in the upper portion of the crown, becoming oblique and then horizontal in the neck and upper part of the root, while towards the lower part of the root they are inclined downwards. In their course they divide and subdivide dichotomously, and, especially in the root, give off minute branches, which join together in loops in the matrix, or end blindly. Near the periphery of the dentine, the finer ramifications of the canaliculi terminate imperceptibly by free ends. The dental canaliculi have definite walls, consisting of an elastic homogeneous membrane, the *dentinal sheath of Neumann*, which resists the action of acids; they contain slender

cylindrical prolongations of the odontoblasts, first described by Tomes, and named *Tomes' fibres* or *dentinal fibres*.

The *matrix* is translucent, and contains the chief part of the earthy matter of the dentine. In it are a number of fine fibrils, which are continuous with the fibrils of the dental pulp. After the earthy matter has been removed by steeping a tooth in weak acid, the animal basis remaining may be torn into laminae which run parallel with the pulp cavity, across the direction of the tubes. These layers may be indicated in a section of dry dentine by a series of somewhat parallel lines—the *contour lines of Owen*—composed of imperfectly calcified dentine. In consequence of the imperfection in the calcifying process, little irregular cavities are left, termed *interglobular spaces* (fig. 978). A series of these spaces is found towards the outer surface of the dentine, where they form a layer which is sometimes known as the *granular layer of Tomes*. They have received their name from the fact that they are surrounded by minute nodules or globules of dentine. Other curved lines may be seen parallel to the surface. These are the *lines of Schreger*, and are due to the optical effect of simultaneous curvature of the dentinal fibres.

Chemical composition.—According to Berzelius and von Bibra, dentine consists of 28 parts of animal and 72 parts of earthy matter. The animal matter is converted by boiling into gelatin. The earthy matter consists of phosphate, carbonate, and a trace of fluoride of calcium, phosphate of magnesium, and other salts; over 80 per cent. of the earthy matter consists of calcium phosphate.

The **enamel** (*substantia adamantina*) is the hardest and most compact part of the tooth, and forms a thin crust over the exposed part of the crown, as far as the commencement of the root. It is thickest on the grinding surface of the crown, until worn away by attrition, and becomes thinner towards the neck. The cement may overlap, or be overlapped by, the enamel, but in the majority the cement and enamel meet without overlapping. Sections usually show a series of brown lines which form acute angles with the contour of the underlying dentine. The enamel consists of minute rods or columns termed *enamel fibres* or *prisms* (*prismata adamantina*). They lie parallel with one another, resting by one extremity upon the dentine, which presents a number of minute depressions for their reception, and forming the free surface of the crown by the other extremity. The columns are directed vertically on the summit of the crown, horizontally at the sides; they are about 4μ in diameter, and pursue a more or less wavy course. Each column is a six-sided prism and presents numerous dark transverse shadings; these shadings are probably due to the manner in which the columns are developed in successive stages, producing shallow constrictions, as will be subsequently explained.

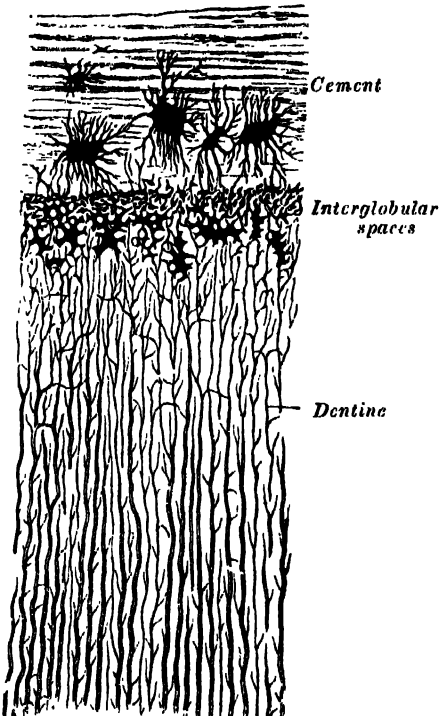
Numerous minute interstices intervene between the enamel fibres near their dentinal ends, a provision calculated to allow of the permeation of fluids from the dental canaliculi into the substance of the enamel.

Chemical composition.—Enamel consists of from 98 to 99 per cent. of earthy matter, and from 1 to 2 per cent. of animal matter. The earthy matter consists of phosphate of lime, with traces of fluoride and carbonate of calcium, phosphate of magnesium, and other salts. According to Tomes there is no animal matter in properly calcified enamel.

The **crusta petrosa** or **cement** (*substantia ossea*) is disposed as a thin layer on the roots of the teeth, from the termination of the enamel to the apex of each root, where it is usually very thick. In structure and chemical composition it resembles bone. It contains, sparingly, the lacunae and canaliculi which characterise true bone; the canaliculi of adjacent lacunae intercommunicate as in ordinary bone; and those more deeply placed join with the adjacent dental canaliculi. Normal cement is non-vascular.

As age advances, the cement increases in thickness, and gives rise to those bony growths or exostoses so common in the teeth of the aged: the pulp cavity also becomes partially filled up by a hard substance, intermediate in structure between dentine and bone (*secondary* or *adventitious dentine*, Tomes). It appears to be formed by a slow conversion of the dental pulp, which shrinks, or even disappears.

FIG. 978.—Transverse section of a portion of the root of a canine tooth. $\times 300$.

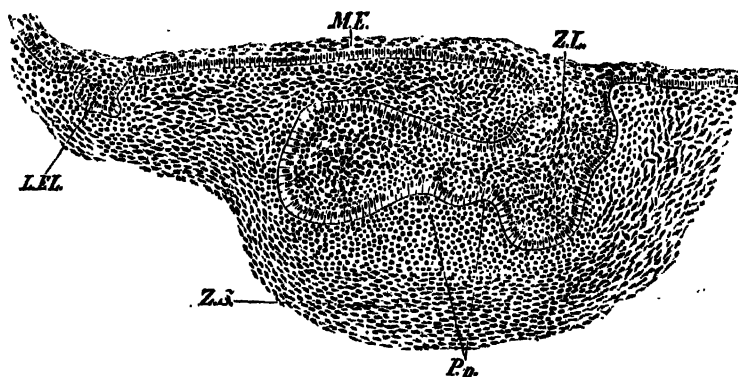


DEVELOPMENT OF THE TEETH (figs. 979 to 982)

In describing the development of the teeth, the mode of formation of the deciduous teeth must first be considered, and then that of the permanent series.

Development of the deciduous teeth.—The development of the deciduous teeth begins about the sixth week of foetal life as a thickening of the epithelium along the line of the future jaw, the thickening being due to a rapid multiplication of the more deeply situated epithelial cells. As the cells multiply they extend into the subjacent mesoderm, and thus form a ridge or strand of cells imbedded in mesoderm. About the seventh week a longitudinal splitting or cleavage of this strand of cells takes place, and it becomes divided into two strands; the separation begins in front and extends laterally, the process occupying four or five weeks. Of the two strands thus formed, the labial forms the *labio-dental lamina*; while the other, the lingual, is the ridge of cells in connexion with which the teeth, both deciduous and permanent, are developed. Hence it is known as the *dental lamina* or *common dental germ*. It forms a flat band of cells, which grows into the substance of the embryonic jaw, at first horizontally inwards, and then, as the teeth develop, vertically, i.e. upwards in the upper jaw, and downwards in the lower jaw. While still maintaining a horizontal direction it has two edges—an *attached edge*, con-

FIG. 979.—A sagittal section through the first lower deciduous molar of a human embryo 30 mm. long. $\times 100$. (Röse.)



L.L., Labio-dental lamina, here separated from the dental lamina. *M.E.*, Mouth-epithelium. *P.p.*, Bicuspidate papilla, capped by the enamel germ. *Z.L.*, placed over the shallow dental furrow, points to the dental lamina, which is spread out below to form the enamel germ of the future tooth. *Z.S.*, Condensed tissue forming dental sac.

tinuous with the epithelium lining the mouth, and a *free edge*, projecting inwards, and imbedded in the mesodermal tissue of the embryonic jaw. Along its line of attachment to the buccal epithelium is a shallow groove, the *dental furrow*.

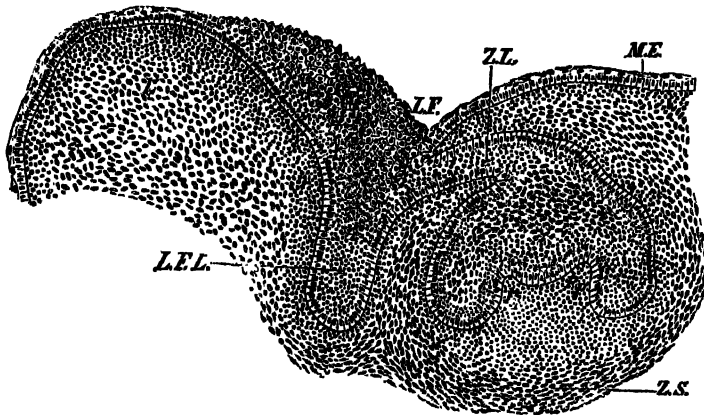
About the ninth week the dental lamina begins to develop enlargements along its free border. These are ten in number in each jaw, and each corresponds with a future deciduous tooth. They consist of masses of epithelial cells; and the cells of the deeper part—that is, the part farthest from the margin of the jaw—increase rapidly and spread out in all directions. Each mass thus comes to assume a club shape, connected with the general epithelial lining of the mouth by a narrow neck, embraced by mesoderm. They are now known as *special dental germs*. After a time the lower expanded portion inclines outwards, so as to form an angle with the superficial constricted portion, which is sometimes known as the *neck* of the special dental germ. About the tenth week the mesodermal tissue beneath these special dental germs becomes differentiated into papillæ; these grow upwards, and come in contact with the epithelial cells of the special dental germs, which become folded over them like a hood or cap. There is, then, at this stage a papilla (or papillæ) which has already begun to assume somewhat the shape of the crown of the future tooth, and from which the dentine and pulp of the tooth are formed, surmounted by a dome or cap of epithelial cells from which the enamel is derived.

In the meantime, while these changes have been going on, the dental lamina has been extending backwards behind the special dental germ corresponding with the second deciduous molar tooth, and at about the seventeenth week of foetal life it presents an enlargement, the special dental germ for the first permanent molar, soon followed by the formation of a papilla in the mesodermal tissue for the same tooth. This is followed, about the fourth month after birth, by a further extension backwards of the dental lamina, with the formation of another enlargement and its corresponding papilla for the second molar. And finally the process is repeated for the third molar, its papilla appearing about the fifth year of life.

After the formation of the special dental germs, the dental lamina undergoes atrophic changes and becomes cribriform, except on the lingual aspect of each of the special germs of the temporary teeth, where it undergoes a local thickening forming the special dental germ of each of the successional permanent teeth—i.e. the ten anterior ones in each jaw. Here the same process goes on as has been described in connexion with those of the deciduous teeth: that is, they recede into the substance of the gum behind the germs of the deciduous teeth. As they recede they become club-shaped, form expansions at their distal extremities, and finally meet papillæ which have been formed in the mesoderm, just in the same manner as was the case in the deciduous teeth. The apex of each papilla indents the dental germ which encloses it, and, forming a cap for it, becomes converted into the enamel, while the papilla forms the dentine and pulp of the permanent tooth.

The special dental germs consist at first of rounded or polyhedral epithelial cells. After the formation of the papillæ, these cells undergo a differentiation into three layers. Those which are in immediate contact with the papilla become elongated, and form a layer of well-marked columnar epithelium coating the papilla. They are the cells which form the enamel fibres, and are therefore termed *enamel cells* or *ameloblasts*. The cells of the outer layer of the special dental germ, which are in contact with the inner surface of the dental sac, presently to be described, are much shorter, cubical in form, and are

FIG. 980.—A sagittal section through the canine tooth of an embryo 40 mm. long. $\times 100$. (Röse.)



L.F. Labiodental furrow. The other lettering as in fig. 979.

named the *external enamel epithelium*. All the intermediate round cells of the dental germ between these two layers undergo a peculiar change. They become stellate in shape and develop processes, which unite to form a network into which fluid is secreted; this has the appearance of a jelly, and to it the names of *enamel pulp* or *stellate reticulum* are given. Between the stellate reticulum and the layer of ameloblasts there is a *stratum intermedium* consisting of two or three layers of round or polygonal cells. This transformed special dental germ is now known under the name of *enamel organ* (fig. 981).

While these changes are going on, a sac is formed around each enamel organ from the surrounding mesodermal tissue. This is known as the *dental sac*, and is a vascular membrane of connective tissue. It grows up from below, and thus encloses the whole tooth germ; as it grows it causes the neck of the enamel organ to atrophy and disappear; so that all communication between the enamel organ and the superficial epithelium is cut off. At this stage there are vascular papillæ surmounted by caps of epithelial cells, the whole being surrounded by membranous sacs.

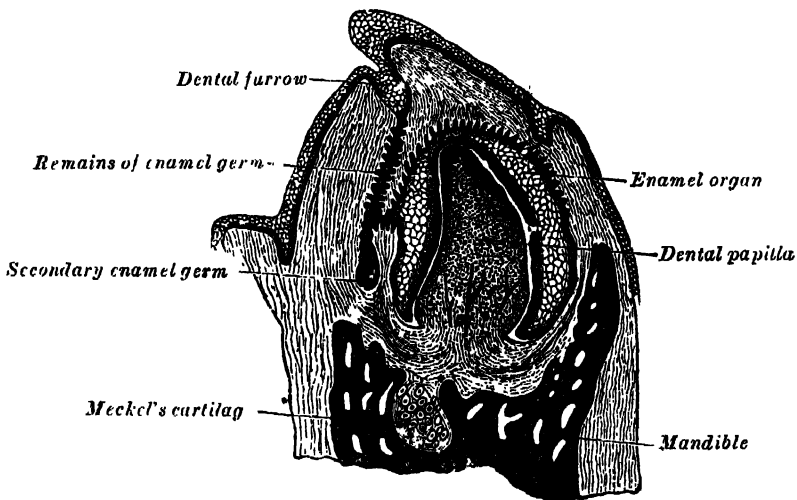
Formation of the enamel.—The enamel is formed exclusively from the enamel cells or ameloblasts of the special dental germ, either by direct calcification of the columnar cells, which become elongated into the hexagonal rods of the enamel, or, as is more generally believed, as a secretion from the ameloblasts, within which calcareous matter is subsequently deposited.

The process begins at the apex of each cusp, at the ends of the enamel cells in contact with the dental papilla. Here a fine globular deposit takes place, being apparently shed from the end of the ameloblasts. It is known by the name of the *enamel droplet*, and resembles keratin in its resistance to the action of mineral acids. This droplet then becomes fibrous and calcifies, and forms the first layer of the enamel; a second droplet now appears and calcifies, and so on; successive droplets of keratin-like material are shed from the ameloblasts and form successive layers of enamel, the ameloblasts gradually receding as each layer is produced, until at the termination of the process they have

almost disappeared. The enamel pulp and stratum intermedium atrophy and disappear, so that the newly formed calcified material and the external enamel epithelium come into apposition. The crown of the tooth is covered for a time by a distinct membrane. This is known as the *cuticula dentis*, or *Nasmyth's membrane*, and is believed to be formed by the external epithelium of the enamel-organ. It forms a horny layer, which may be separated from the subjacent calcified mass by the action of strong acids. It is marked by the hexagonal impressions of the enamel prisms, and, when stained by nitrate of silver, shows the characteristic lines of interepithelial cement.

Formation of the dentine.—While these changes are taking place in the epithelium to form the enamel, contemporaneous changes occurring in the differentiated mesoderm of the dental papillæ result in the formation of the dentine. As before stated, the first germs of the dentine are the papillæ, corresponding in number with the teeth, formed from the soft mesodermal tissue which bounds the depressions containing the special enamel germs. The papillæ grow upwards into the enamel germs and become covered by them, both being enclosed in a vascular connective tissue, the dental sac, in the manner above described. Each papilla then consists of rounded cells, and is very vascular, and soon begins to assume the shape of the future tooth. The next step is the appearance of the *odontoblasts*, which have a relation to the development of the teeth similar to that of the osteoblasts to the formation of bone. They are formed from the cells of the periphery of the

FIG. 981.—A vertical section of the mandible of an early human fœtus. $\times 25$.



papilla—that is to say, from the cells in immediate contact with the ameloblasts of the special dental germ. These cells become elongated, one end of the elongated cell resting against the epithelium of the special dental germs, the other being tapered and often branched. By the direct transformation of the peripheral ends of these cells, or by a secretion from them, a layer of uncalcified matrix (*prodentine*) is formed which caps the cusp, or cusps if there be more than one, of the papillæ. This matrix becomes fibrillated, and in it islets of calcification make their appearance, and, coalescing, give rise to a continuous layer of calcified material which covers each cusp and constitutes the first layer of dentine. The odontoblasts retire towards the centre of the papilla, and, as they do so, produce successive layers of dentine from their peripheral extremities—that is to say, they form the dental matrix in which calcification subsequently takes place. As they thus recede from the periphery of the papilla, they leave behind them filamentous processes of cell protoplasm, provided with finer side processes; these are surrounded by calcified material, and thus form the dental canaliculi, and, by their side branches, the anastomosing canaliculi; the processes of protoplasm contained within these constitute the dentinal fibres (Tomes' fibres). In this way the entire thickness of the dentine is developed, the wall of each canaliculus being completed throughout its whole length by a single odontoblast. The central part of the papilla does not undergo calcification, but persists as the pulp of the tooth. In certain places uncalcified portions of the matrix remain between the successive layers of dentine, and give rise to the interglobular spaces alluded to above.

Formation of the cement.—The root of the tooth begins to be formed shortly before the crown emerges through the gum, but is not completed until some time afterwards. Its form is determined by a downgrowth of the epithelium of the dental germ, which extends

below the region where the enamel is to be formed, almost as far as the situation of the apex of the future root (fig. 982). This fold of epithelium is known as the *epithelial sheath*, and on its papillary surface odontoblasts appear, which in turn form dentine, so that the dentine formation is identical in the crown and root of the tooth. The vascular tissues of the dental sac then break through the epithelial sheath, and spread over the surface of the root as a layer of bone-forming material. In this layer osteoblasts make their appearance, and the process of ossification goes on in identically the same manner as in the ordinary intramembranous ossification of bone. The remains of the epithelial sheath may sometimes be seen in the adult as isolated groups of cells in the alveolodental periosteum.

Formation of the alveoli.—About the fourteenth week of embryonic life the dental lamina becomes enclosed in a trough or groove of mesodermal tissue, which at first is common to all the dental germs, but subsequently becomes divided by bony septa into loculi, each locus containing the special dental germ of a deciduous tooth and its corresponding permanent tooth. After birth each cavity becomes subdivided, so as to form separate loculi (the future alveoli) for the deciduous tooth and its corresponding permanent tooth. Although at one time the whole of the growing tooth is contained in the cavity of the alveolus, the latter never completely encloses it, since there is always an aperture over the top of the crown filled by soft tissue, by which the dental sac is connected with the surface of the gum, and which in the permanent teeth is called the *gubernaculum dentis*.

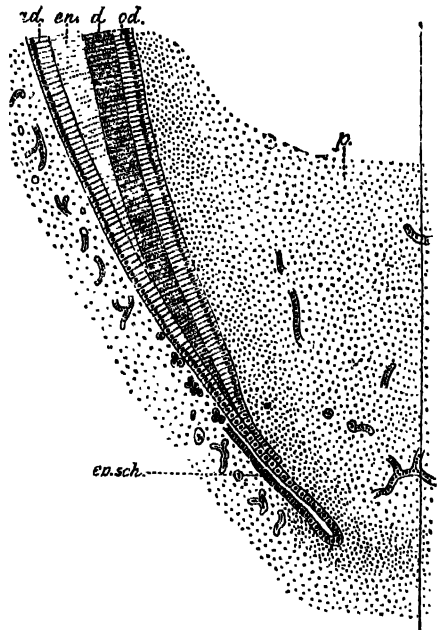
Development of the permanent teeth.—The permanent teeth as regards their development may be divided into two sets: (1) those which replace the deciduous teeth, and which, like them, are ten in number in each jaw; these are the *successional permanent teeth*; and (2) those which have no deciduous predecessors, but are superadded distal to the temporary dental series. These are three in number on either side in each jaw, and are termed *superadded permanent teeth*. They are the three molars of the permanent set, the molars of the deciduous set being replaced by the premolars of the permanent set. The development of the successional permanent teeth—the ten anterior ones in either jaw—has already been indicated. During their development the permanent teeth, enclosed in their sacs, come to be placed on the lingual side of the deciduous teeth and more distant from the margin of the future gum, and, as already stated, are separated from them by bony partitions. As the crown of the permanent tooth grows, absorption of these bony partitions and of the root of the deciduous tooth takes place, through the agency of *osteoclasts* which appear at this time, and finally nothing but the crown of the deciduous tooth remains. This is shed or removed, and the permanent tooth takes its place.

The superadded permanent teeth are developed in the manner already described, by extensions backward of the posterior part of the dental lamina in each jaw.

Eruption.—When the calcification of the different tissues of the tooth is sufficiently advanced to enable it to bear the pressure to which it will be afterwards subjected, eruption takes place, the tooth making its way through the gum. The gum is absorbed by the pressure of the crown of the tooth against it, which is itself pressed up by the increasing size of the root. At the same time the septa between the dental sacs ossify, and separate the alveoli; these firmly embrace the necks of the teeth, and afford them a solid basis of support.

The eruption of the deciduous teeth commences about the seventh month after birth, and is completed about the end of the second year, the teeth of the lower jaw preceding those of the upper.

FIG. 982.—A longitudinal section of the lower part of a growing tooth, showing the extension of the layer of ameloblasts beyond the crown to mark off the limit of formation of the dentine of the root. (Rösc.) (From Quain's Elements of Anatomy, Vol. II. Part I.)



ad. Ameloblasts, continuous below with the epithelial sheath. d. Dentine. en. Enamel. od. Odontoblasts. p. Pulp.

The following, according to C. S. Tomes, are the most usual times of eruption of the deciduous teeth :

Lower central incisors	6 to 9 months
Upper incisors	8 to 10 months
Lower lateral incisors and first molars	15 to 21 months
Canines	16 to 20 months
Second molars	20 to 24 months

There are, however, considerable variations in these times. According to Holt : a child at the age of one year should have six teeth ; at the age of a year and a half, twelve teeth ; at the age of two years, sixteen teeth ; and at the age of two and a half years, twenty teeth.

Calcification of the permanent teeth proceeds in the following order in the lower jaw (in the upper jaw it takes place a little later) : the first molar, soon after birth ; the central and lateral incisors, and the canine, about six months after birth ; the premolars, at the second year, or a little later ; the second molar, about the end of the second year ; the third molar, about the twelfth year.

The eruption of the permanent teeth takes place at the following periods, the teeth of the lower jaw preceding those of the upper by short intervals :

First molars	6th year
Two central incisors	7th year
Two lateral incisors	8th year
First premolars	9th year
Second premolars	10th year
Canines	11th to 12th year
Second molars	12th to 13th year
Third molars	17th to 25th year

Towards the sixth year, before any of the deciduous teeth are shed, there are twenty-four teeth in each jaw, viz. the ten deciduous teeth and the crowns of all the permanent teeth except the third molars.

Applied Anatomy.—As a consequence of local irritation or of chronic digestive disturbances occurring during their eruption, both the deciduous and the permanent teeth may show defective development or irregular transverse furrowing and erosions ; this is particularly the case with the incisors. Quite distinct from, and much less common than this, is a characteristic malformation of the two upper central permanent incisors seen in patients with inherited syphilis, and first described by Hutchinson. Here there is a crescentic notch in the anterior surface and at the cutting edge of the tooth, which is pug-shaped, stunted, and set obliquely in the gum, pointing either medialwards or lateralwards. Numerous forms of innocent *tumour* arising from the teeth, or from their constituent layers, have been described under the general name of *odontoma*. Infection of the pulp of a tooth by bacteria gaining access thereto in consequence of dental caries gives rise to the common and very painful *alveolar abscess* ; starting in the apical space between the root of the tooth and its alveolar socket, the pus from such an abscess may make its way into the maxillary antrum, or burst through the hard palate or cheek. A more superficial abscess forming between the root of a tooth and the gum is known as a *gum-boil*.

THE TONGUE (LINGUA)

The tongue is the principal organ of the sense of taste, and an important organ of speech ; it also assists in the mastication and deglutition of the food. It is situated in the floor of the mouth, within the curve of the body of the mandible.

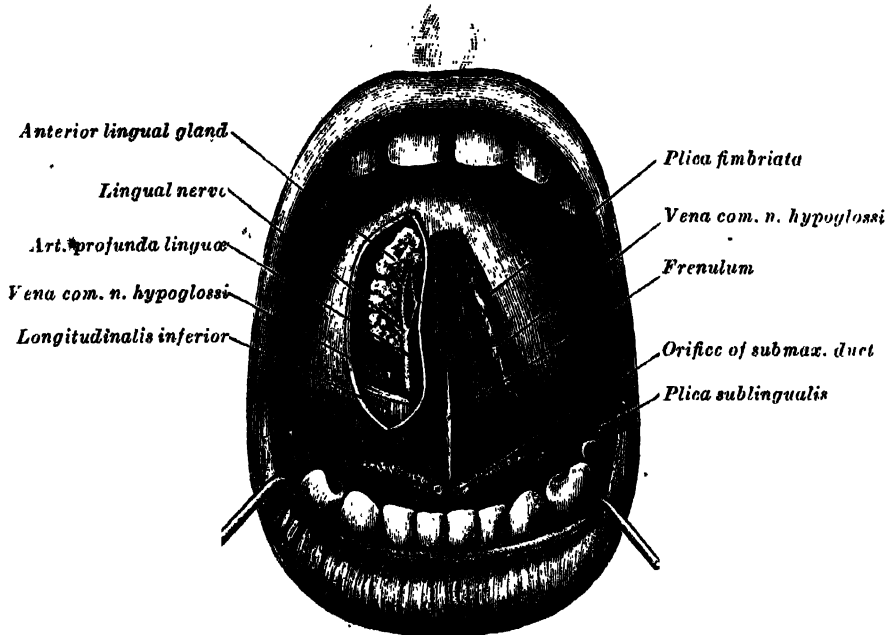
Its *root* (fig. 942) is connected with the hyoid bone by the Hyoglossi and Genioglossi muscles and the hyoglossal membrane ; with the epiglottis by three *glosso-epiglottic* folds of mucous membrane ; with the soft palate by the glossopalatine arches ; and with the pharynx by the Constrictores pharyngis superiores and the mucous membrane. Its *apex*, thin and narrow, is directed forwards against the lingual surfaces of the lower incisor teeth. Its *inferior surface* (fig. 983) is connected with the mandible by the Genioglossi ; from it the mucous membrane passes across the floor of the mouth to the lingual surface of the gum ; and, in the middle line, is elevated into a vertical fold, the *frenulum lingue*. On either side of the frenulum is a slight fold of the mucous

membrane, the *plica fimbriata*, the free edge of which occasionally exhibits a series of fringe-like processes.

The apex, sides and dorsum, and part of the inferior surface of the tongue are free.

The *dorsum* of the tongue (fig. 984) is convex and divided by a *median sulcus* which ends behind, about 3 cm. from the root of the tongue, in a depression, the *foramen cæcum*; from this foramen a shallow groove, the *sulcus terminalis*, runs lateralwards and forwards on either side to the margin of the tongue. The part in front of this groove, forming about two-thirds of the dorsum, looks upwards, and is rough and covered with papillæ; the posterior third is directed

FIG. 983.—The mouth cavity. The apex of the tongue is turned upwards, and on the right side a superficial dissection of its under surface has been made.



backwards and is smoother; it contains numerous muciparous glands and lymph follicles (*lingual tonsil*). The *foramen cæcum* is the remains of the upper part of the *thyroglossal duct* or diverticulum from which the thyroid gland is developed; the pyramidal lobe of the thyroid gland indicates the position of the lower part of the duct (p. 131).

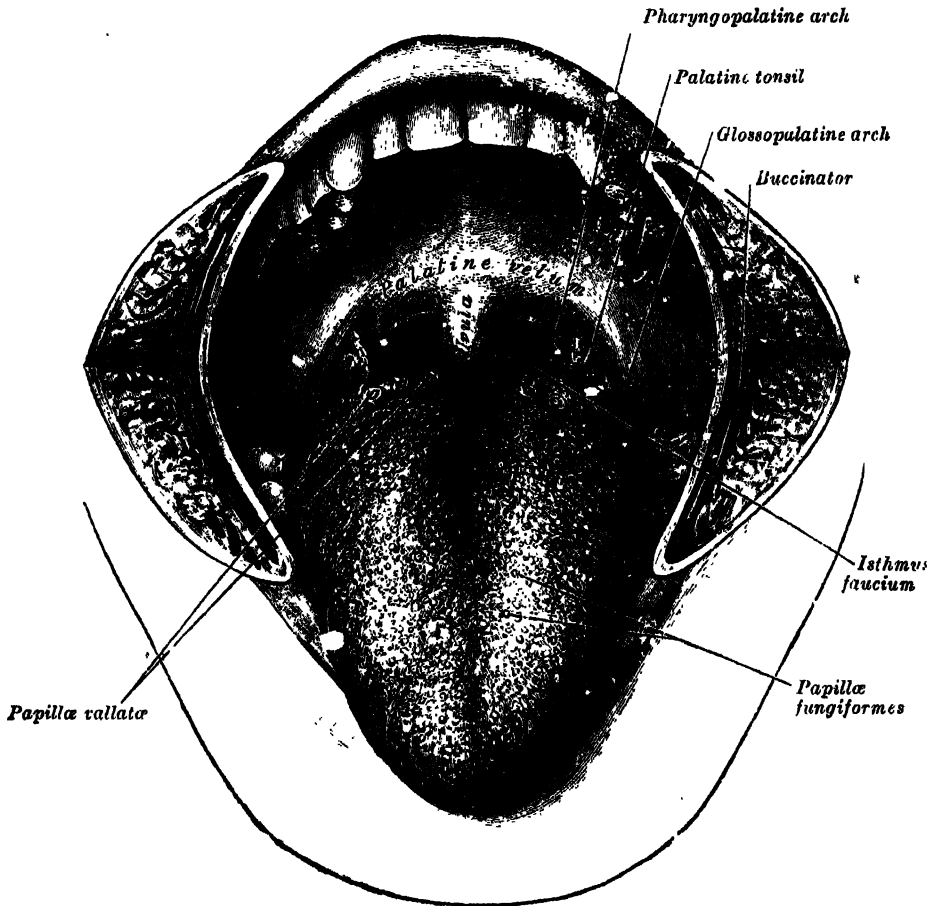
The *papillæ of the tongue* (fig. 984) are projections of the corium. They are thickly distributed over the anterior two-thirds of the dorsum, giving to this part its characteristic roughness. The papillæ are grouped under the terms *papillæ vallatæ*, *papillæ fungiformes*, *papillæ conicæ*, and *papillæ simplices*.

The *papillæ vallatæ* (fig. 985) are of large size, and vary from eight to twelve in number. They are situated on the dorsum of the tongue, and form a V-shaped row immediately in front of the *sulcus terminalis*. Each papilla is from 1 mm. to 2 mm. in diameter, and is attached to the bottom of a circular depression of the mucous membrane; each depression is surrounded by a wall (*vallum*), and between this and the papilla is a circular sulcus or fossa. The papilla is

shaped like a truncated cone, the smaller end being attached to the tongue; the broader end projects a little above the surface of the tongue, and is studded with numerous small secondary papillæ. The entire papilla and the surrounding fossa and vallum are covered by stratified squamous epithelium.

The *papillæ fungiformes* (fig. 987), more numerous than the preceding, are found chiefly at the sides and apex of the tongue, but are scattered irregularly and sparingly over the dorsum. They are easily distinguished from the papillæ

FIG. 984.—The mouth cavity. The cheeks have been slit transversely and the tongue pulled forwards.



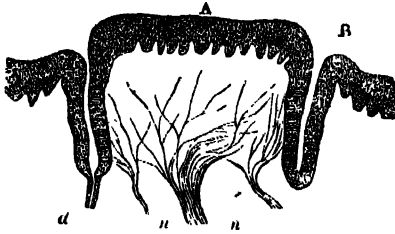
conicæ by their large size, rounded shape, and deep red colour. They are narrow at their attachment to the tongue, but broad and rounded at the free extremities, and covered with secondary papillæ. On the sides of the tongue, where they are somewhat flattened, they are termed *papillæ lenticulares*.

The *papillæ conicæ* (fig. 986) cover the anterior two-thirds of the dorsum. They are very minute, conical or cylindrical in shape, and arranged in lines parallel with the two rows of the papillæ vallatæ, excepting at the apex of the tongue, where their direction is transverse. Like the vallate and fungiform papillæ, the papillæ conicæ present numerous secondary papillæ which are, however, more pointed and contain a larger proportion of elastic fibres. The epithelium covering the papillæ conicæ may be split up into filamentous processes, each of which forms the apex of one of the secondary papillæ; these

processes are of a whitish tint, owing to the thickness and density of the epithelium of which they are composed, and which has here undergone a peculiar modification, the cells having become cornified and elongated.

The *papillæ simplices* are similar to those of the skin, and cover the whole of the mucous membrane of the tongue, as well as the larger papillæ. They consist of closely set microscopic elevations of the corium, each containing a capillary loop, covered by a layer of epithelium.

FIG. 985.—A vertical section of a papilla vallata of a calf. (Engelmann.)



A. The papilla. B. The surrounding wall. d. Duct of a lingual gland. n. Nerves.

FIG. 986.—A papilla conica. Magnified.



Muscles of the tongue.—The tongue is divided into right and left halves by a median fibrous septum which extends throughout its entire length and is fixed below to the hyoid bone. In either half there are two sets of muscles, extrinsic and intrinsic; the former have their origins outside the tongue, the latter are contained entirely within it.

The *extrinsic muscles* (fig. 988) are :

Genioglossus.
Hyoglossus.

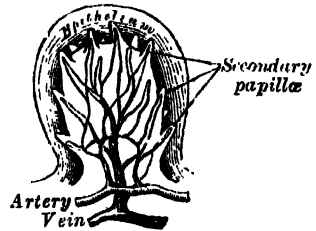
Chondroglossus.
Styloglossus.

Glossopalatinus.*

The **Genioglossus** is a triangular muscle placed close to and parallel with the median plane. It arises by a short tendon from the superior mental spine on the inner surface of the symphysis menti, immediately above the Geniohyoideus, and spreads out in a fan-like form. The inferior fibres are attached by a thin aponeurosis to the upper part of the body of the hyoid bone, a few passing between the Hyoglossus and Chondroglossus to blend with the Constrictores pharyngis; the middle fibres pass backwards, and the superior ones upwards and forwards, to enter the whole length of the under surface of the tongue, from the root to the apex. The muscles of opposite sides are separated posteriorly by the median fibrous septum of the tongue; in front, they are more or less blended owing to the decussation of fasciculi in the median plane.

The **Hyoglossus**, thin and quadrilateral, arises from the front of the lateral part of the body and from the whole length of the greater cornu of the hyoid bone; it passes almost vertically upwards and enters the side of the tongue, between the Styloglossus and Longitudinalis inferior. The fibres arising from the body of the hyoid bone overlap those from the greater cornu.

FIG. 987.—A section of a papilla fungiformis. Magnified.

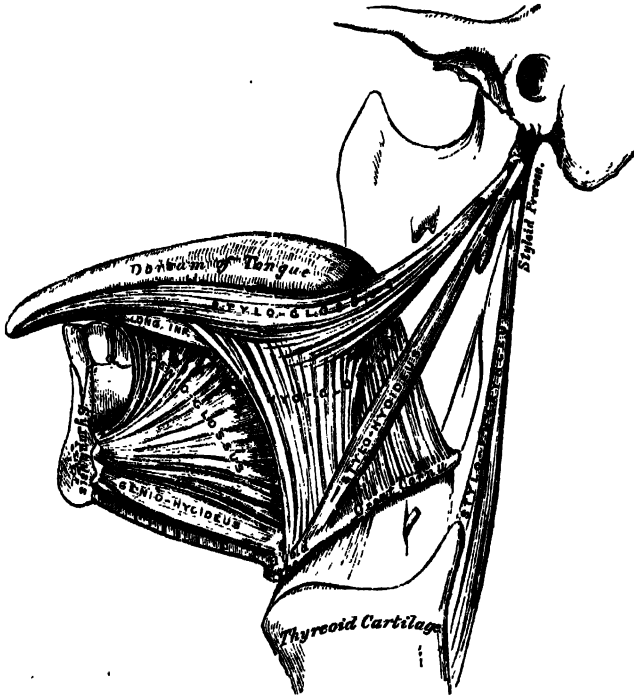


* The *Glossopalatinus* (Palatoglossus), although one of the muscles of the tongue, is more closely associated with the soft palate both in situation and function; it is consequently described with the muscles of that structure (p. 1075).

Relations.—The Hyoglossus is in relation by its *superficial surface* with the Digastricus, the Stylohyoideus, Styloglossus, and Mylohyoideus, the submaxillary ganglion, the lingual and hypoglossal nerves, the ranine vein, the sublingual gland, the deep portion of the submaxillary gland, and the submaxillary duct. By its *deep surface* it is in relation with the stylohyoid ligament, the Genioglossus, Longitudinalis linguae inferior, and Constrictor pharyngis medius, the lingual vessels, and the glossopharyngeal nerve.

The **Chondroglossus** is sometimes described as a part of the Hyoglossus, but is separated from it by fibres of the Genioglossus which pass to the side of the pharynx. It is about 2 cm. long, and arises from the medial side and base of the lesser cornu and contiguous portion of the body of the hyoid bone; it ascends and blends with the intrinsic muscular fibres of the tongue, between the Hyoglossus and Genioglossus.

FIG. 988.—The extrinsic muscles of the tongue. Left side.



A small slip arises occasionally from the cartilago triticea in the lateral hyothyroid ligament and enters the tongue with the hindermost fibres of the Hyoglossus.

The **Styloglossus**, the shortest and smallest of the three styloid muscles, arises from the anterior and lateral surfaces of the styloid process, near its apex, and from the stylomandibular ligament. Passing downwards and forwards between the internal and external carotid arteries, it divides upon the side of the tongue into two portions; one, longitudinal, enters the side of the tongue near its dorsal surface, blending with the fibres of the Longitudinalis linguae inferior in front of the Hyoglossus; the other, oblique, overlaps the Hyoglossus and decussates with its fibres.

The *intrinsic muscles* (fig. 989) are:

Longitudinalis linguae superior.
Longitudinalis linguae inferior.

Transversus linguae.
Verticalis linguae.

The **Longitudinalis linguae superior** is a thin stratum of oblique and longitudinal fibres immediately underlying the mucous membrane on the

dorsum of the tongue. It arises from the submucous fibrous layer close to the epiglottis, and from the median fibrous septum, and runs forward to the edges of the tongue.

The *Longitudinalis linguae inferior* is a narrow band situated on the under surface of the tongue between the *Genioglossus* and *Hyoglossus*. It extends from the root to the apex of the tongue, some of its posterior fibres being connected with the body of the hyoid bone; in front it blends with the fibres of the *Styloglossus*.

The *Transversus linguae* consists of fibres which arise from the median fibrous septum and pass lateralwards to be inserted into the submucous fibrous tissue at the sides of the tongue.

The *Verticalis linguae* is found only at the borders of the fore part of the tongue. Its fibres extend from the upper to the under surface of the organ.

Applied Anatomy.—The median fibrous septum of the tongue is very complete, so that the anastomosis between the two lingual arteries is not very free. This is a point of considerable importance in connexion with removal of one-half of the tongue for cancer, an operation frequently resorted to when the disease is strictly confined to one side of the organ. If the mucous membrane be divided exactly in the middle line, the tongue can be split into halves, without any appreciable hæmorrhage, and the diseased half can then be removed.

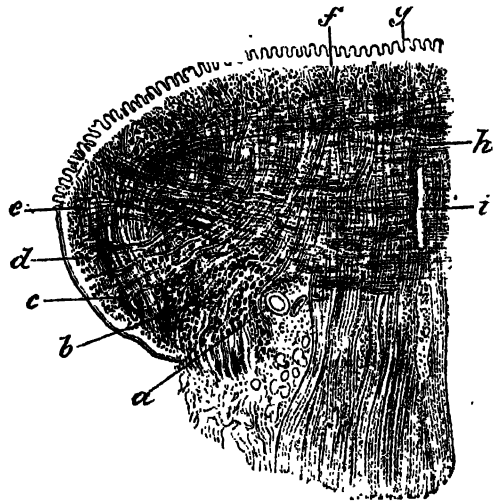
Nerves.—The muscles of the tongue described above are supplied by the hypoglossal nerve.

Actions.—The *Genioglossi* draw the tongue forwards, and protrude the apex from the mouth. The two muscles acting in their entirety draw the tongue downwards, so as to make its superior surface concave from side to side forming a channel along which fluids may pass towards the pharynx, as in sucking. The *Hyoglossi* depress the tongue; the *Styloglossi* draw it upwards and backwards. The *Glossopalatini* raise the root of the tongue. The intrinsic muscles are mainly concerned in altering the shape of the tongue; thus, the *Longitudinales linguae superior* and *inferior* tend to shorten it, but the former, in addition, turns the tip and sides upwards so as to render the dorsum concave, while the latter pulls the tip downwards and renders the dorsum convex. The *Transversus linguae* narrows and elongates the tongue, and the *Verticalis linguae* flattens and broadens it. The complex arrangement of the lingual muscles enables the tongue to assume the forms necessary for the production of the different consonantal sounds; and Macalister * states 'there is reason to believe that the musculature of the tongue varies in different races owing to the hereditary practice and habitual use of certain motions required for enunciating the several vernacular languages.'

Structure of the tongue.—The tongue is partly invested by mucous membrane and a submucous fibrous layer.

The mucous membrane covering the under surface of the tongue is thin, smooth, and identical in structure with that lining the rest of the oral cavity. The mucous membrane of the dorsum of the tongue behind the sulcus terminalis is thick and freely movable over the subjacent parts. It contains a large number of lymphoid follicles, which together constitute what is sometimes termed the *lingual tonsil*. Each follicle forms a rounded eminence, the centre of which is perforated by a minute orifice leading into a funnel-shaped cavity or recess; around this recess are grouped numerous oval or rounded

FIG. 989.—A coronal section of the tongue, showing the intrinsic muscles. (Altered from Krause.)



a. Lingual artery. b. Longitudinalis inferior. c. Hyoglossus. d. Styloglossus. e. Insertion of Transversus. f. Longitudinalis superior. g. Papillae of tongue. h. Vertical fibres of Genioglossus intersecting Transversus. i. Septum.

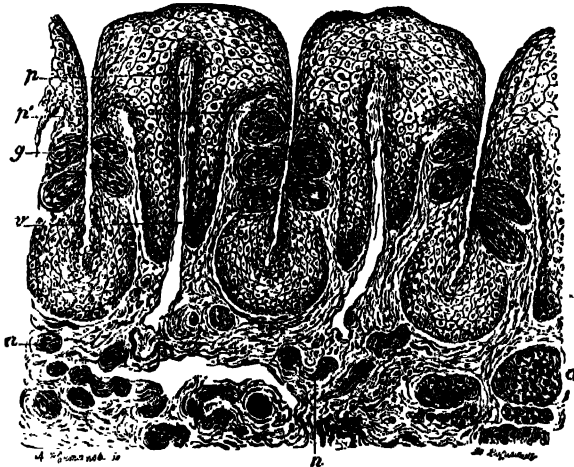
nodules of lymphoid tissue, each enveloped by a capsule derived from the submucous fibrous layer, while opening into the bottom of the recesses are also seen the ducts of mucous glands. The mucous membrane on the anterior part of the dorsum of the tongue is thin, intimately adherent to the muscular tissue, and presents numerous minute surface eminences, the *papillæ* of the tongue. It consists of a layer of connective tissue, the *corium* or *mucosa*, covered with epithelium.

The epithelium is of the stratified squamous variety, similar to, but much thinner and less complex than that of the skin; and each papilla has a separate investment from root to summit.

The *corium* consists of a dense felt-work of fibrous connective tissue, with numerous elastic fibres, firmly connected with the fibrous tissue forming the septa between the muscular bundles of the tongue. It contains the ramifications of the numerous vessels and nerves from which the papillæ are supplied, large plexuses of lymphatic vessels, and the glands of the tongue.

Structure of the papillæ.—The papillæ apparently resemble in structure those of the cutis, consisting of cone-shaped projections of connective tissue, covered with a thick layer of stratified squamous epithelium, and containing one or more capillary loops, among which nerves are distributed in great abundance, especially in the vallate and fungiform papillæ. They exhibit secondary papillæ, as already described.

FIG. 990.—A vertical section of a papilla foliata of a rabbit, passing across the folia. (Ranvier.)



a. Serous gland. g. Gustatory calyx. n. Nerve-bundles. p. Central lamina of corium. v. Lateral lamina. v. Section across a sinus-like vein, which traverses the whole length of the folium.

Glands of the tongue.—The tongue is provided with mucous and serous glands.

The *mucous glands* are similar in structure to the labial and buccal glands. They are found especially at the back part behind the vallate papillæ, but are also present at the apex and marginal parts. In this connexion the anterior lingual glands of Blandin or Nuhn require special notice. They are situated on the under surface of the apex of the tongue (fig. 983), one on either side of the frenulum, where they are covered by a fasciculus of muscular fibres derived from the Styloglossus and Longitudinalis inferior. They are from 12 mm. to 25 mm. long, and about 8 mm. broad, and each opens by three or four ducts on the under surface of the apex.

The *serous glands* occur only at the back of the tongue in the neighbourhood of the taste-buds, their ducts opening for the most part into the fossæ of the vallate papillæ. These glands are racemose, the duct of each branching into several minute ducts, which end in alveoli lined by a single layer of more or less columnar epithelium. Their secretion is of a watery nature, and probably assists in the distribution of the substance to be tasted over the taste area (Ebner).

The *septum* consists of a vertical layer of fibrous tissue, extending throughout the entire length of the median plane of the tongue, though not quite reaching the dorsum. It is thicker behind than in front, and occasionally contains a small fibrocartilage, about 6 mm. in length. It is well displayed by making a vertical section across the organ.

The *hyoglossal membrane* is a strong fibrous lamina, which connects the under surface of the root of the tongue to the body of the hyoid bone and gives attachment to the inferior fibres of the Genioglossi.

Taste-buds, the end-organs of the gustatory sense, are scattered over the mucous membrane of the mouth and tongue at irregular intervals. They occur especially in the

sides of the vallate papillæ. In the rabbit there is a localised area at the side of the base of the tongue, the *papilla foliata*, in which they are specially abundant (fig. 990). They are described under the organs of the senses (p. 942).

Vessels and Nerves.—The main artery of the tongue is the lingual branch of the external carotid, but the external maxillary and ascending pharyngeal arteries also give branches to it. The veins open into the internal jugular vein.

The lymphatics of the tongue are described on p. 718.

The sensory nerves of the tongue are: (1) the lingual branch of the mandibular, which is the nerve of ordinary sensibility for the anterior two-thirds of the tongue; (2) the chorda tympani branch of the facial, which runs in the sheath of the lingual, and is generally regarded as the nerve of taste for the anterior two-thirds; this nerve is a continuation of the sensory root of the facial (nervus intermedius); (3) the lingual branch of the glossopharyngeal, which is distributed to the mucous membrane at the base and sides of the tongue, and to the papillæ vallatæ, and is the nerve of taste and of general sensation to this region; (4) the superior laryngeal, which sends some fine branches to the root near the epiglottis.

Applied Anatomy.—The tongue is liable to numerous diseases, and any or all of its tissues—muscles, connective tissue, mucous membrane, glands, vessels, nerves, and lymphatics—may undergo morbid changes. It is not often the seat of congenital defects, though a few cases of vertical cleft have been recorded, and it is occasionally, though much more rarely than is commonly supposed, the seat of 'tongue tie,' from shortness of the frenulum.

There is one condition which may be regarded as congenital, the so-called macro-glossia, though sometimes it does not evidence itself until a year or two after birth. This is an enlargement of the tongue which is due primarily to a dilatation of the lymph-channels and a greatly increased development of the lymphatic tissue throughout the organ. It is often aggravated by inflammatory changes induced by injury or exposure, and the tongue may assume enormous dimensions and hang out of the mouth, giving the child an imbecile expression. The treatment consists in excising a V-shaped portion and bringing the cut surfaces together with deeply placed sutures.

Acute inflammation of the tongue is attended by great swelling from infiltration of its connective tissue. This may render the patient incapable of swallowing or speaking, may seriously impede respiration, or may end in suppuration, and the formation of an acute abscess.

In all ages the mucous membrane of the tongue has received much sedulous consideration in disease, and it is certain that the amount and the distribution of the 'fur' with which it may be covered often give valuable help in diagnosis. The fur consists of proliferating or desquamated epithelium, bound up with inspissated mucus, the débris of food, and bacteria of all sorts. The mucous membrane of the tongue may become chronically inflamed, and presents different appearances in the various stages of the disease, to which the terms leucoplakia and psoriasis linguæ have been given. They are usually the result of syphilis.

The tongue is frequently the seat of ulceration, which may arise from many causes, as from the irritation of jagged teeth, dyspepsia, tuberculosis, syphilis, and cancer. Of these the cancerous ulcer is the most important and also the most common. The variety is the squamous epithelioma, which soon develops into an ulcer with an indurated edge. It causes great pain, which speedily extends to all parts supplied with sensation by the mandibular nerve, especially to the region of the ear (auriculotemporal nerve).

Cancer of the tongue may necessitate removal of a part or the whole of the organ, and many different methods have been adopted for its excision. It may be removed from the mouth by the scissors; this is usually known as Whitehead's method; and it will generally be sufficient if half the organ is removed. The mouth is widely opened with a gag, and the tongue transfixed with a silk ligature, by which to hold and make traction on it; it is then split down the median septum, and the reflection of mucous membrane from the tongue to the jaw, and the insertion of the Genioglossus on the affected side are divided with a pair of curved, blunt-pointed scissors. The tongue can now be pulled well out of the mouth and its base is cut through by a series of short snips until the main artery is reached, this being securely ligatured. In the event of the artery being accidentally injured, hæmorrhage can be at once controlled by passing the forefinger over the tongue till it touches the epiglottis, and then turning it towards the side on which the artery is to be compressed, and pushing it forcibly against the jaw (Heath). If the disease has spread to the glossopalatine arch, the Glossopalatinus must be divided higher up than usual, and in some cases, before division, it can be stripped from the buccopharyngeal aponeurosis together with the tonsil, and removed along with half the tongue.

In cases where the submaxillary lymph-glands are involved, an operation in the neck should be resorted to. Having performed a preliminary tracheotomy, Kocher removes the tongue from the neck by an incision from near the lobule of the auricula, down the anterior border of the Sternocleidomastoideus to the level of the greater cornu of the hyoid bone, then forwards to the body of the hyoid bone, and upwards to near the symphysis menti. The lingual artery is secured, and by a careful dissection the submaxillary lymph-glands and the tongue are removed. If the lymph-glands in the submaxillary

region are in any way affected, an extensive dissection of these will be required if there is any chance of eradicating the disease, and for this purpose it will be found necessary to remove the submaxillary salivary gland.

The more recent operations aim at, first, clearing the neck thoroughly of affected glands, both in the submaxillary region and along the carotid sheath; and, secondly, removal of the tongue from within the mouth, leaving if possible the floor of the mouth intact, so as to avoid soiling the large wound in the neck by the discharges from the mouth.

THE FAUCES (fig. 984)

The aperture by which the mouth communicates with the pharynx is called the *isthmus faucium*. It is bounded, above, by the soft palate; below, by the dorsum of the tongue; and on either side, by the glossopalatine arch.

The *glossopalatine arch* (anterior pillar of the fauces) on either side runs downwards, lateralwards, and forwards from the inferior surface of the soft palate to the side of the tongue, and is formed by the projection of the *Glossopalatinus* with its covering mucous membrane.

The *pharyngopalatine arch* (posterior pillar of the fauces) is larger and projects farther towards the middle line than the glossopalatine; it runs downwards, lateralwards, and backwards from the margin of the uvula to the side of the pharynx, and is formed by the projection of the *Pharyngopalatinus*, covered by mucous membrane. The arches are separated below by a triangular interval, the *sinus tonsillaris*, in which the palatine tonsil is lodged.

The *palatine tonsils* are two masses of lymphoid tissue, situated in the lateral walls of the oral part of the pharynx. Each tonsil occupies the lower part of the triangular interval (*sinus tonsillaris*) between the glossopalatine and pharyngopalatine arches; the upper part of the sinus is known as the *supratonsillar fossa*. A crescentic or triangular fold of mucous membrane, within which is a layer of fibrous tissue continuous with the capsule of the tonsil, passes backwards from the glossopalatine arch. The upper part of this fold, termed the *plica semilunaris*, or *plica supratonsillaris*, stretches between the two arches and forms the medial wall of the supratonsillar fossa; the lower part of the fold, named the *plica triangularis*, forms the medial wall of the anterior and lower parts of the sinus tonsillaris; it overlaps, and is frequently adherent to, the tonsil. The tonsil extends forwards for a variable distance under cover of the *plica triangularis* and the glossopalatine arch, and upwards around the supratonsillar fossa and into the soft palate. A considerable part of the tonsil is therefore below the level of the surrounding mucous membrane (i.e. imbedded), while the remainder projects as the visible tonsil. In the child the tonsils are relatively (and frequently absolutely) larger than in the adult, and about one-third of the tonsil is imbedded (Hett and Butterfield *). After puberty the imbedded portion diminishes considerably in size, and the tonsil assumes a disc-like form, flattened from side to side; the shape and size of the tonsil, however, vary considerably in different individuals.

The *free surface* of the tonsil presents from twelve to fifteen orifices leading into small crypts or recesses from which numerous follicles branch out into the tonsillar substance.

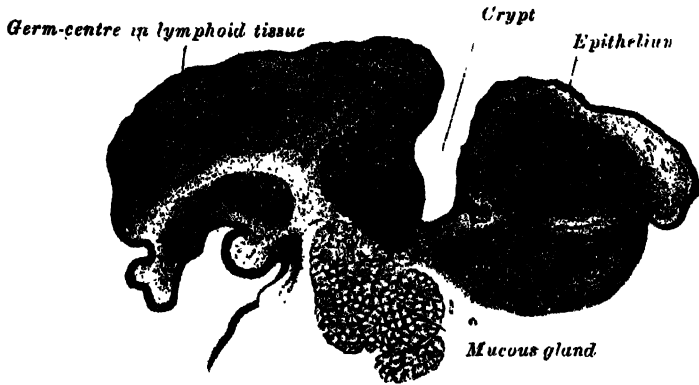
The *lateral or deep surface* is adherent to a fibrous capsule which is continued into the *plica triangularis*. This surface is separated from the Constrictor pharyngis superior by some loose connective tissue; this muscle intervenes between the tonsil and the external maxillary artery with its tonsillar and ascending palatine branches. Some muscular fibres are inserted into the lower and posterior parts of the capsule. The internal carotid artery lies behind and lateral to the tonsil at a distance of about 25 mm. from it.

In the operation of 'enucleation' of the tonsil, advantage is taken of the fact that its deep surface is encapsuled, the entire tonsil and the capsule being removed.

The palatine tonsils form part of a circular band of adenoid tissue which guards the opening into the digestive and respiratory tubes. The anterior part of the ring is formed by the submucous adenoid collections (*lingual tonsil*)

on the posterior part of the tongue; the lateral portions consist of the palatine tonsils and the adenoid collections in the vicinity of the auditory tubes, while the ring is completed behind by the pharyngeal tonsil on the posterior wall of the pharynx. In the intervals between these main masses are smaller collections of adenoid tissue.

FIG. 991.—Vertical section of the tonsil of a dog. $\times 15$.



Structure (fig. 991).—The crypts of the tonsil are lined by stratified squamous epithelium, continuous with that of the mucous membrane of the pharynx. In the recesses the epithelium is closely applied to the lymphoid tissue which forms the substance of the tonsil, and is invaded by numerous lymph-corpuscles. Probably some of the latter pass into the mouth and form the so-called salivary corpuscles. The lymphoid tissue is arranged in nodules or follicles aggregated together. The lymphocytes are less closely packed in the centre of each nodule which is described as a *germ centre*, because multiplication of the corpuscles goes on in this situation. Mucous glands are found subjacent to the tonsil; their ducts open into the tonsillar crypts. Surrounding each follicle is a close plexus of lymphatics, from which the lymphatic vessels pass to the deep cervical lymph-glands in the neighbourhood of the greater cornu of the hyoid bone, behind and below the angle of the mandible (p. 717).

Vessels and Nerves.—The *arteries* supplying the tonsil are the dorsalis linguae from the lingual, the ascending palatine and tonsillar from the external maxillary, the ascending pharyngeal from the external carotid, the descending palatine branch of the internal maxillary, and a twig from the small meningeal.

The *veins* end in the tonsillar plexus, on the lateral side of the tonsil.

The *nerves* are derived from the sphenopalatine ganglion, and from the glossopharyngeal nerve.

Applied Anatomy.—The palatine tonsils can be easily inspected by instructing the patient to throw the head back and open his mouth widely; the tongue at the same time being depressed by a spatula or tongue-depressor. The normal tonsil should not project beyond the plane of the glossopalatine arch. They are prone to become enlarged, especially in tuberculous children; and when much increased in size they cause great trouble, owing to obstruction to respiration and deglutition. The tonsils may be the seat of acute inflammation, which may run on to suppuration, requiring evacuation of the pus. The incision into the tonsil should always be made from in front backwards and medialwards. Another form of acute inflammation of the tonsil is follicular tonsillitis, due to the lodgment of micro-organisms in the crypts of the tonsil. The removal of an enlarged tonsil is, as a rule, a very simple operation, and is not usually attended with much hæmorrhage, unless the patient is suffering from hæmophilia. The tonsil may be the seat of malignant growth, either an epithelioma or a lymphosarcoma.

Palatine aponeurosis.—Attached to the posterior border of the hard palate is a thin, firm fibrous lamella which supports the muscles and gives strength to the soft palate. It is thicker above than below, where it becomes very thin and difficult to define. Laterally it is continuous with the tendon of the Tensor veli palatini.

Blakeway* maintains that the palatine aponeurosis is not a separate structure, but is actually the expanded tendon of the Tensor veli palatini.

* *Journal of Anatomy and Physiology*, vol. xlviii.

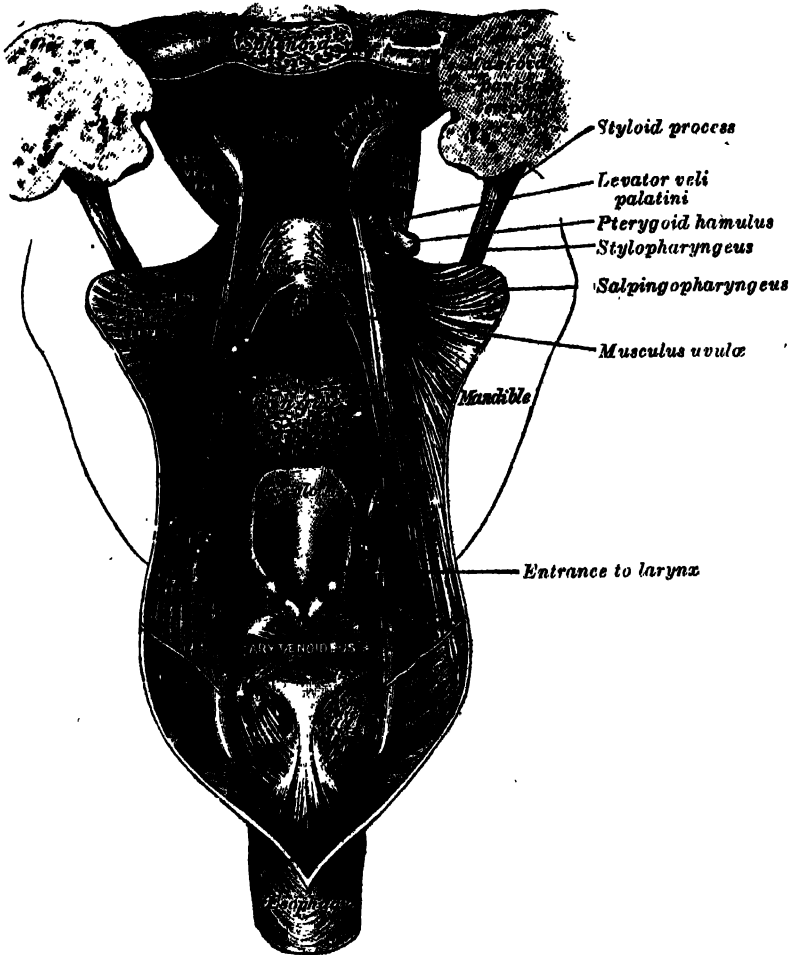
Muscles of the palate and fauces (fig. 992):

Levator veli palatini.
Tensor veli palatini.
Musculus uvulæ.

Glossopalatinus.
Pharyngopalatinus.

The **Levator veli palatini** (*Levator palati*) is a thick, rounded muscle situated laterally to the choana. It arises from the under surface of the petrous part of the temporal bone, immediately in front of the lower opening of the

FIG. 992.—Dissection of the muscles of the palate from behind.



carotid canal, and from the medial lamina of the cartilage of the auditory tube. After passing above the upper concave margin of the Constrictor pharyngis superior, and in front of the Salpingopharyngeus, it spreads out in the palatine velum, its fibres extending obliquely downwards and medialwards to the middle line, where they blend with those of the opposite side.

The **Tensor veli palatini** (*Tensor palati*) is a broad, thin, muscle placed laterally to the Levator veli palatini. It arises by a flat lamella from the scaphoid fossa at the base of the medial pterygoid lamina, from the medial surface of the spina angularis of the sphenoid, and from the lateral lamina of the cartilage of the auditory tube. Descending vertically between the medial pterygoid lamina and the Pterygoideus internus, it ends in a tendon which winds round the pterygoid hamulus, being retained in this situation by some

of the fibres of origin of the *Pterygoideus internus*. Between the tendon and the hamulus is a small bursa. The tendon then passes medialwards, and is inserted into the palatine aponeurosis and into the surface behind the transverse ridge on the horizontal part of the palatine bone.

The *Musculus uvulæ* (*Azygos uvulæ*) arises from the posterior nasal spine of the palatine bones and from the palatine aponeurosis; it descends to be inserted into the uvula.

The *Glossopalatinus* (*Palatoglossus*) is a small fleshy fasciculus, narrower in the middle than at either end, forming, with the mucous membrane covering its surface, the glossopalatine arch. It arises from the anterior surface of the soft palate, where it is continuous with the muscle of the opposite side, and passing downwards, forwards, and lateralwards in front of the palatine tonsil, is inserted into the side of the tongue, some of its fibres spreading over the dorsum, and others passing deeply into the substance of the organ to intermingle with the *Transversus linguae*.

The *Pharyngopalatinus* (*Palatopharyngeus*) is a long, fleshy fasciculus narrower in the middle than at either side, forming, with the mucous membrane covering its surface, the pharyngopalatine arch. It is separated from the *Glossopalatinus* by an angular interval, in which the palatine tonsil is lodged. It arises from the soft palate, where it is divided into two fasciculi by the *Levator veli palatini* and *Musculus uvulæ*. The *posterior fasciculus* lies in contact with the mucous membrane, and joins with that of the opposite muscle in the middle line; the *anterior fasciculus*, the thicker, lies in the soft palate between the *Levator* and *Tensor*, and joins in the middle line the corresponding part of the opposite muscle. Passing lateralwards and downwards behind the palatine tonsil, the *Pharyngopalatinus* joins the *Stylopharyngeus*, and is inserted with that muscle into the posterior border of the thyroid cartilage, some of its fibres ending on the side of the pharynx, and others passing across the middle line posteriorly, to decussate with the muscle of the opposite side.

In a dissection of the soft palate from its posterior or pharyngeal surface to its anterior or oral surface, the muscles would be exposed in the following order, viz. the posterior fasciculus of the *Pharyngopalatinus*, covered by a continuation of the mucous membrane of the floor of the nasal cavities; the *Musculus uvulæ*; the *Levator veli palatini*; the anterior fasciculus of the *Pharyngopalatinus*; the aponeurosis of the *Tensor veli palatini*; and the *Glossopalatinus*, covered by a continuation of the oral mucous membrane.

Nerves.—The *Tensor veli palatini* is supplied by a branch from the otic ganglion; the remaining muscles of this group are in all probability supplied by the accessory nerve through the pharyngeal plexus.*

Actions.—During the *first stage* of deglutition, the bolus of food is driven back into the fauces by the pressure of the tongue against the hard palate, the base of the tongue being, at the same time, retracted, and the larynx raised, with the pharynx. During the second stage the entrance to the larynx is closed by the drawing forward of the arytaenoid cartilages towards the cushion of the epiglottis—a movement produced by the contraction of the *Thyroarytaenoidei*, the *Arytaenoidei*, and the *Arytaenoepiglottidei*.

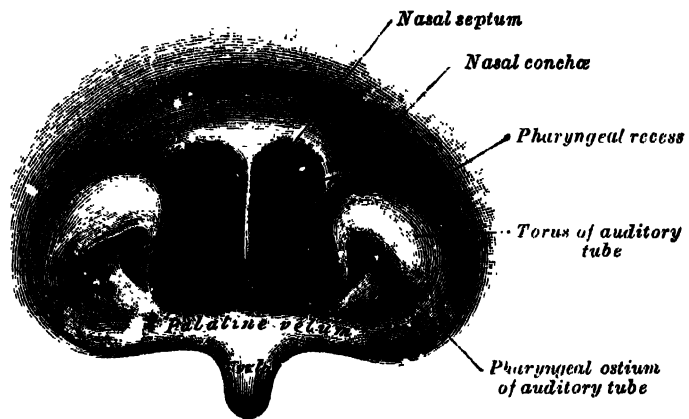
After leaving the tongue the bolus passes on to the posterior or laryngeal surface of the epiglottis, and glides along this for a certain distance; then the *Glossopalatini*, the constrictors of the fauces, contract behind it; the palatine velum is slightly raised by the *Levator veli palatini*, and made tense by the *Tensor veli palatini*; and the *Pharyngopalatini*, by their contraction, pull the pharynx upwards over the bolus, and come nearly together, the uvula filling up the slight interval between them. By these means the food is prevented from passing into the nasal part of the pharynx; at the same time, the *Pharyngopalatini* form an inclined plane, directed obliquely downwards and backwards, along the under surface of which the bolus descends into the lower part of the pharynx. The *Salpingopharyngei* raise the upper and lateral parts of the pharynx, i.e. those parts which are above the points where the *Stylopharyngei* are attached to the pharynx.

* The innervation of the soft palate, by Aldren Turner, *Journal of Anatomy and Physiology*, vol. xxiii.

THE PHARYNX

The **pharynx** is the part of the digestive tube which is placed behind the nasal cavities, mouth, and larynx. It is a musculomembranous tube, about 14 cm. long, which extends from the under surface of the skull to the sixth cervical vertebra and the lower border of the cricoid cartilage. Its width varies at different levels; just below the base of the skull, at the level of the pharyngeal recesses or fossæ of Rosenmüller (p. 1077) it is 3·5 cm., while at the lower part of the laryngeal opening, opposite the pyriform sinuses (p. 1077), it is 4·5 cm.; at the junction of the pharynx with the œsophagus it is only about 1·5 cm. It is limited, *above*, by the body of the sphenoid and basilar part of the occipital bone; *below*, it is continuous with the œsophagus; *posteriorly*, it is connected by loose areolar tissue with the cervical portion of the vertebral column and the prevertebral fascia covering the Longus colli and Longus capitis muscles; *anteriorly*, it is incomplete, and is attached, from above downwards, to the medial pterygoid lamina, pterygomandibular raphe, mandible

FIG. 993.—Front of nasal part of pharynx, as seen with the laryngoscope.



tongue, hyoid bone, and thyreoid and cricoid cartilages; *laterally*, it is connected to the styloid processes and their muscles, and is in contact with the common and internal carotid arteries, the internal jugular veins, the glossopharyngeal, vagus, and hypoglossal nerves, and the sympathetic trunks, and above with small parts of the Pterygoidei interni. It communicates with the nasal cavities, the tympanic cavities, the mouth, the larynx, and the œsophagus. The cavity of the pharynx may be subdivided from above downwards into three parts: nasal, oral, and laryngeal (fig. 963).

The **nasal part of the pharynx** (nasopharynx) lies behind the nose and above the level of the soft palate. With the exception of the soft palate its walls are immovable, and consequently its cavity is never obliterated; in this respect it differs from the oral and laryngeal parts. In front (fig. 993) it communicates through the choanæ with the nasal cavities. Behind the lower edge of the soft palate it opens into the oral part of the pharynx. In the act of swallowing this opening is closed by the elevation of the soft palate. On its lateral wall is the *pharyngeal ostium of the auditory tube*, somewhat triangular in shape, and bounded behind by a firm prominence, the *torus* or *cushion*, caused by the medial end of the projecting cartilage of the auditory tube which elevates the mucous membrane. A vertical fold of mucous membrane, the *salpingopharyngeal fold*, stretches from the lower part of the torus to the wall of the pharynx; it contains the Salpingopharyngeus muscle. A second and smaller fold, the *salpingopalatine fold*, stretches from the upper part of the torus to the palate. Behind the torus is a deep recess, the *pharyngeal recess* or

fossa of Rosenmüller. On the posterior wall is a prominence, best marked in childhood, produced by a mass of lymphoid tissue, which is known as the *pharyngeal tonsil*.

The pharyngeal tonsil is visible to the naked eye during the later months of foetal life and usually increases in size up to the age of six or seven years, after which it not infrequently begins to atrophy. In a child of eighteen months it forms a triangular prominence the apex of which is near the nasal septum, and the base at the junction of the roof and posterior wall of the nasal part of the pharynx. The prominence consists of a number of folds which radiate forwards and laterally towards a median recess, the *pharyngeal bursa*. The folds consist mainly of diffuse adenoid tissue, but there are also some deeply placed mucous glands. The pharyngeal bursa lies close to the base of the tonsil and presents the appearance of a blind recess.*

The oral part of the pharynx reaches from the soft palate to the level of the hyoid bone. It opens anteriorly, through the isthmus faucium, into the mouth, while in its lateral wall, between the two palatine arches, is a triangular recess, in which the palatine tonsil is lodged (p. 1072).

The laryngeal part of the pharynx reaches from the hyoid bone to the lower border of the cricoid cartilage, where it is continuous with the oesophagus. In the upper part of its anterior wall is the triangular entrance of the larynx, the base of which is directed forwards and is formed by the epiglottis, while its lateral boundaries are constituted by the aryepiglottic folds. On either side of the laryngeal orifice is a recess, the *sinus piriformis*, bounded medially by the aryepiglottic fold, and laterally by the thyroid cartilage and hyothyroid membrane.

FIG. 994.—The muscles of the pharynx and cheek.



Structure.—The pharynx is composed, from within outwards, of three coats: mucous, fibrous and muscular, the last being covered by the thin buccopharyngeal fascia (p. 486).

The *mucous coat* is continuous with that lining the auditory tubes, the nasal cavities, the mouth, and the larynx. In the nasal part of the pharynx its epithelium is columnar and ciliated; in the oral and laryngeal portions the epithelium is stratified squamous. Between the region covered by ciliated columnar epithelium and that covered by squamous epithelium, there is a narrow intermediate zone where the epithelium is cubical, and the cilia are imperfect or absent. Superiorly, this zone lies near the nasal septum; laterally it passes over the orifice of the auditory tube and inclines backwards at the union of the soft palate with the lateral wall. Beneath the mucous membrane are found racemose mucous glands; they are especially numerous at the upper part of the pharynx around the orifices of the auditory tubes.

The *fibrous coat* is situated between the mucous and muscular layers. It is thick above (pharyngobasilar fascia) where the muscular fibres are wanting, and is firmly connected to the basilar portion of the occipital and the petrous portions of the temporal bones. As it descends it diminishes in thickness, and is gradually lost. It is strengthened posteriorly by a strong fibrous band, which is attached above to the pharyngeal spine on the under surface of the basilar portion of the occipital bone, and passes downwards, forming a median raphe, which gives attachment to the Constrictor-pharyngis.

The *muscular coat* consists of the muscles of the pharynx.

* Consult article by J. Synnington, *British Medical Journal*, Oct. 15, 1910.

Muscles of the pharynx.—The muscles of the pharynx (fig. 994) are :

Constrictor pharyngis inferior.
Constrictor pharyngis medius.
Constrictor pharyngis superior.

Stylopharyngeus.
Salpingopharyngeus.
Pharyngopalatinus.*

The **Constrictor pharyngis inferior** is the thickest of the constrictors. It arises from the cricoid cartilage in the interval between the Cricothyroideus in front, and the articular facet for the inferior cornu of the thyroid cartilage behind. It arises from the oblique line on the lamina of the thyroid cartilage, from the surface behind this line nearly as far as the posterior border, and from the inferior cornu. From these origins the fibres spread backwards and medially to be inserted with the muscle of the opposite side into a fibrous raphe in the posterior median line of the pharynx. The inferior fibres are horizontal and continuous with the circular fibres of the œsophagus; the rest ascend, increasing in obliquity, and overlap the Constrictor medius.

Relations.—The Constrictor pharyngis inferior is covered by the buccopharyngeal fascia (p. 436) which surrounds the entire pharynx. *Behind*, the muscle is in relation with the vertebral column and the prevertebral fascia and muscles; *laterally*, with the thyroid gland, the common carotid artery, and the Sternothyroideus; by its *internal surface*, with the Constrictor pharyngis medius, the Stylopharyngeus, the Pharyngopalatinus and the pharyngeal aponeurosis. The internal branch of the superior laryngeal nerve and the laryngeal branch of the superior thyroid artery run near the upper border, and the recurrent nerve and the laryngeal branch of the inferior thyroid artery pass beneath the lower border of this muscle, before they enter the larynx.

The **Constrictor pharyngis medius** is a fan-shaped muscle which arises from the lesser cornu, and from the whole length of the upper border of the greater cornu of the hyoid bone, and from the lower part of the stylohyoid ligament. The fibres diverge from their origin: the lower ones descend beneath the Constrictor inferior, as far as the lower end of the pharynx, the middle fibres pass transversely, and the upper fibres ascend and overlap the Constrictor superior. It is inserted, with the muscle of the opposite side, into the posterior median fibrous raphe.

Relations.—The Constrictor pharyngis medius is separated from the Constrictor pharyngis superior by the glossopharyngeal nerve, the Stylopharyngeus and the stylohyoid ligament; and from the Constrictor pharyngis inferior by the internal branch of the superior laryngeal nerve and laryngeal branch of the superior thyroid artery. *Behind*, it lies on the prevertebral fascia, the Longus colli, and the Longus capitis. *Laterally* it is in relation with the carotid vessels, the pharyngeal plexus, and some lymph-glands. Near its origin it is covered by the Hyoglossus, from which it is separated by the lingual vessels. Its *internal surface* lies upon the Constrictor pharyngis superior, the Stylopharyngeus, the Pharyngopalatinus and the pharyngeal aponeurosis.

The **Constrictor pharyngis superior** is a quadrilateral muscle, thinner and paler than the other two. It arises from the lower third of the posterior margin of the medial pterygoid lamina and its hamulus, from the pterygo-mandibular raphe, from the alveolar process of the mandible above the posterior end of the mylohyoid line, and by a few fibres from the side of the tongue. The fibres curve backwards to be inserted into the median raphe, being also prolonged by means of an aponeurosis to the pharyngeal spine on the basilar part of the occipital bone. The superior fibres arch beneath the Levator veli palatini and the auditory tube. The interval between the upper border of the muscle and the base of the skull is closed by the pharyngobasilar fascia (pharyngeal aponeurosis), and is known as the sinus of Morgagni.

Relations.—The Constrictor pharyngis superior is in relation by its *outer surface* with the prevertebral fascia and muscles, the vertebral column, the internal carotid and ascending pharyngeal arteries, the internal jugular vein and pharyngeal venous plexus, the glossopharyngeal, vagus, hypoglossal and lingual nerves, the sympathetic trunks, the Constrictor pharyngis medius and Pterygoideus internus, the styloid process, the stylohyoid ligament, and the Stylopharyngeus. By its *internal surface* it is in relation with the Pharyngopalatinus, the capsule of the palatine tonsil and the pharyngeal

* The Pharyngopalatinus is described with the muscles of the palate (p. 1075).

aponeurosis. Its lower border is separated from the Constrictor pharyngis medius by the Stylopharyngeus and the glossopharyngeal nerve. In front it is separated from the Buccinator by the pterygomandibular raphe.

The **Stylopharyngeus** (fig. 988) is a long, slender muscle which is cylindrical above and flattened below. It arises from the medial side of the base of the styloid process of the temporal bone, passes downwards along the side of the pharynx between the Constrictor pharyngis superior and the Constrictor pharyngis medius, and spreads out beneath the mucous membrane. Some of its fibres are lost in the constrictor muscles, while others, joining with the Pharyngopalatinus, are inserted into the posterior border of the thyroid cartilage. The glossopharyngeal nerve winds round the lateral side of this muscle to reach the tongue.

The **Salpingopharyngeus** (fig. 992) arises from the inferior part of the cartilage of the auditory tube near its pharyngeal orifice; it passes downwards and blends with the posterior fasciculus of the Pharyngopalatinus.

Nerves.—The Constrictores and the Salpingopharyngeus are supplied by the pharyngeal plexus, and the Stylopharyngeus by the glossopharyngeal nerve. The Constrictor pharyngis inferior receives additional branches from the external laryngeal and recurrent nerves.

Actions.—When deglutition is about to be performed, the pharynx is drawn upwards and dilated in different directions, to receive the food propelled into it from the mouth. The Stylopharyngei, which are much farther removed from one another at their origins than at their insertions, draw the sides of the pharynx upwards and lateralwards, and so increase its transverse diameter; its anteroposterior diameter is increased by the larynx and tongue being carried forwards in their ascent. As soon as the bolus of food is received in the pharynx, the elevator muscles relax, the pharynx descends, and the Constrictores contract upon the bolus, and convey it downwards into the oesophagus.

Applied Anatomy.—Hypertrophy of the lymphoid tissue in the nasal part of the pharynx, commonly known as 'adenoids,' is a frequent cause of mouth-breathing and all its attendant disadvantages and dangers in children. It entails a proneness to inflammation of all parts of the air-passages and of the auditory tubes, and leads to deformed development of the palate and dental arch. In many cases adenoids tend to atrophy about the age of puberty, by which time their presence is likely to have caused permanent injury to the health and development of the patient.

The internal carotid artery is in close relation with the pharynx, so that its pulsations can be felt through the mouth. It has been occasionally wounded by sharp-pointed instruments, introduced into the mouth and thrust through the wall of the pharynx. In aneurysm of this vessel in the neck, the tumour necessarily bulges into the pharynx, as this is the direction in which it meets with the least resistance, nothing lying between the vessel and the mucous membrane except the thin Constrictor muscles, whereas on the lateral side there are the dense cervical fascia, the muscles descending from the styloid process and the margin of the Sternocleidomastoideus.

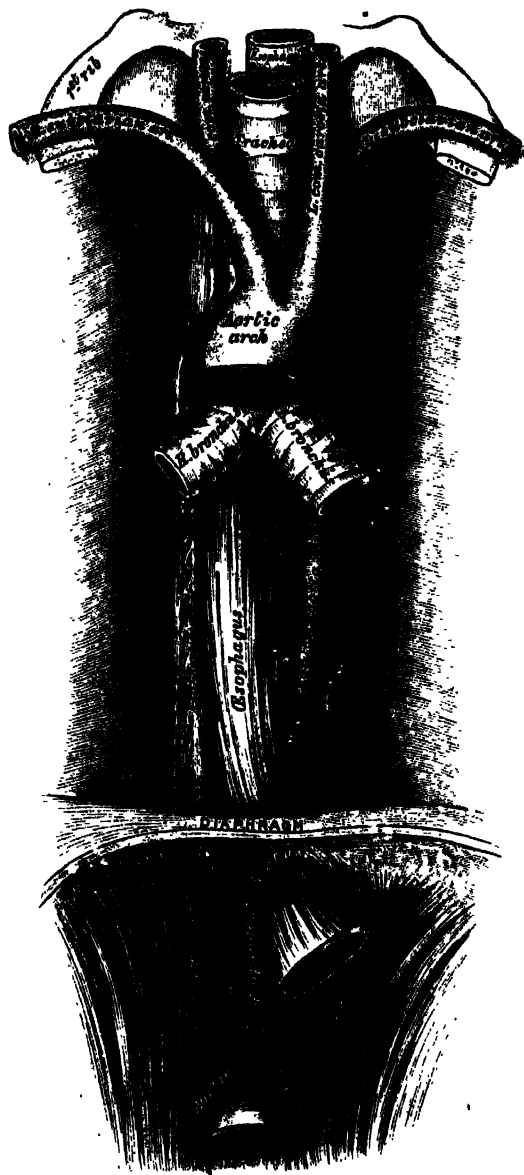
The mucous membrane of the pharynx is very vascular, and is often the seat of inflammation, frequently of a septic character, since the numerous recesses are prone to lodge micro-organisms. And, in addition, owing to its exposed situation, the mucous membrane is liable to be irritated by agents introduced during inspiration. The inflammation may be attended with serious consequences: it may extend up the auditory tube and involve the middle ear; it may spread to the entrance of the larynx, causing oedema and seriously interfering with respiration; or, invading the lymphatics, it may spread to the loose areolar tissue surrounding the pharyngeal wall, and may extend far and wide, sometimes into the posterior mediastinal cavity along the oesophagus. Abscess may form in the connective tissue behind the pharynx, between it and the vertebral column, constituting what is known as *retropharyngeal abscess*. This may be due to caries of the cervical vertebrae, or may be caused by suppuration of the lymph-glands, which are situated in this position opposite the epistropheus, and which receive lymphatics from the nasal cavities. In these cases the pus may be easily evacuated by incision with a guarded bistoury, through the mouth, but it is preferable that the abscess should be opened from the neck. In some instances this is perfectly easy: the abscess can be felt bulging at the side of the neck, and merely requires an incision for its relief; but this is not always so, and then an incision should be made along the posterior border of the Sternocleidomastoideus and the deep fascia divided. A director is now to be inserted into the wound, the forefinger of the left hand being introduced into the mouth and pressure made upon the swelling. This acts as a guide, and the director is to be pushed onwards until pus appears in the groove. A pair of sinus forceps is now inserted along the director and the opening into the cavity dilated.

Abscess also occurs in children, underneath the mucous membrane, between it and the pharyngeal aponeurosis. The condition usually arises from a peritonsillar inflammation, which spreads backwards. In some cases an enormous swelling may form, which pushes forwards the soft palate and gives rise to respiratory obstruction. In such cases the abscess should be opened through the mouth with the child in the inverted position, so as

to prevent the first gush of pus from entering the larynx.

Foreign bodies not infrequently become lodged in the pharynx, and most usually at its termination at about the level of the cricoid cartilage, just beyond the reach of the finger, as the distance from the arch of the teeth to the commencement of the œsophagus is about 15 cm.

FIG. 995.—The œsophagus.



THE ŒSOPHAGUS (fig. 995).

The œsophagus, or gullet, is a muscular canal, from 23 cm. to 25 cm. long, extending from the pharynx to the stomach. It begins in the neck at the lower border of the cricoid cartilage, opposite the sixth cervical vertebra, where it is continuous with the lower end of the pharynx. It descends along the front of the vertebral column, through the superior and posterior mediastinal cavities, passes through the Diaphragm into the abdomen, and ends at the cardiac orifice of the stomach, opposite the tenth thoracic vertebra. The general direction of the œsophagus is vertical; but it presents two slight curves in its course. At its commencement it is placed in the middle line; but it inclines to the left side as far as the root of the neck, gradually passes again to the middle line, which it reaches at the level of the fifth thoracic vertebra, and again deviates to the left as it passes forwards to the œsophageal hiatus in the Diaphragm. The œsophagus also presents anteroposterior flexures corresponding to the curvatures of the cervical and thoracic portions of the vertebral column. It is the narrowest

part of the digestive tube, and is constricted, (a) at its commencement, (b) where it is crossed by the left bronchus, and (c) where it pierces the Diaphragm.

Relations.—The cervical portion of the œsophagus is in relation, *in front*, with the trachea, and at the lower part of the neck, where it projects to the left side, with the thyroid gland; *behind*, it rests upon the vertebral column and Longus colli muscles; *on either side* it is in relation with the common carotid artery (especially the left), and parts of the lobes of the thyroid gland; the recurrent nerves ascend between it and the trachea; to its left side is the thoracic duct.

The thoracic portion of the œsophagus is at first situated in the superior mediastinal cavity between the trachea and the vertebral column, a little to the left of the median line. It then passes behind and to the right of the aortic arch and descends in the posterior mediastinal cavity, along the right side of the descending aorta, then runs in front and a little to the left of the aorta, and enters the abdomen through the Diaphragm at the level of the tenth thoracic vertebra. It is in relation, *in front*, with the trachea, the left bronchus, the pericardium, and the Diaphragm; *behind*, it rests upon the vertebral column, the Longus colli muscles, the right aortic intercostal arteries, the thoracic duct, and the hemiazygos and accessory hemiazygos veins; and below, near the Diaphragm, upon the front of the aorta. On its *left* side, in the superior mediastinal cavity are the terminal part of the aortic arch, the left subclavian artery, the thoracic duct, and left pleura, while running upwards in the angle between it and the trachea is the left recurrent nerve; below, it is in relation with the descending thoracic aorta. On its *right* side are the right pleura, and the azygos vein which it overlaps. Below the roots of the lungs the vagi descend in close contact with it, the right nerve behind, and the left nerve in front of it; the two nerves unite to form a plexus around the tube.

In the lower part of the posterior mediastinal cavity the thoracic duct lies to the right side of the œsophagus; higher up, it is placed behind it, and crossing about the level of the fourth thoracic vertebra, is continued upwards on its left side.

The abdominal portion of the œsophagus is named the *antrum cardiacum*; it lies in the œsophageal groove on the posterior surface of the left lobe of the liver. It measures about 1.25 cm. in length, and only its front and left aspects are covered by peritoneum. It is conical in shape, and curved sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach.

Structure (fig. 996).—The œsophagus has four coats: an external or fibrous, a muscular, a submucous or areolar, and an internal or mucous coat.

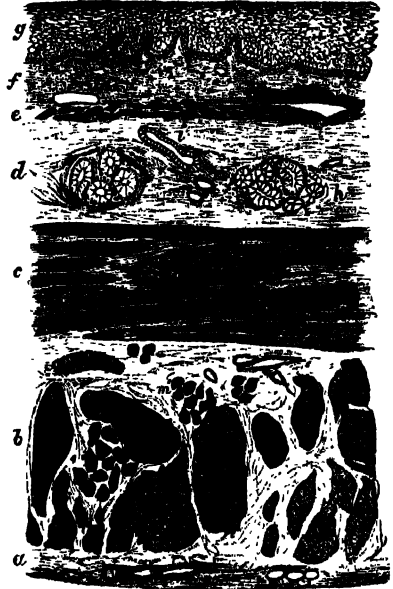
The *fibrous coat* consists of a layer of areolar tissue, containing many elastic fibres.

The *muscular coat* is composed of two layers of considerable thickness: an external of longitudinal and an internal of circular fibres.

The *longitudinal fibres* form a complete investment for nearly the whole of the œsophagus, but at the upper part of the back of the tube, at a point between 8 cm. and 4 cm. below the cricoid cartilage, they diverge from the middle line and form two longitudinal fasciculi which incline upwards and forwards to the front of the tube. Here they pass beneath the lower border of the Constrictor pharyngis inferior and end in a stout tendon, which is attached to the upper part of the ridge on the posterior surface of the lamina of the cricoid cartilage. The V-shaped interval between the diverging longitudinal fasciculi is filled in by the circular fibres of the œsophagus, thinly covered below by some decussating longitudinal fibres, and above by the overlapping lower edge of the Constrictor pharyngis inferior.

Accessory slips of muscular fibres pass between the œsophagus and the left pleura where the latter covers the thoracic aorta, or the root of the left bronchus, or the back of the pericardium.

FIG. 996.—A section of the human œsophagus. (From a drawing by V. Horsley.) Moderately magnified. (From Quain's Elements of Anatomy, Vol. II. Pt. II.)



The section is transverse and from near the middle of the gullet. *a*. Fibrous covering. *b*. Divided fibres of longitudinal muscular coat. *c*. Transverse muscular fibres. *d*. Submucous or areolar layer. *e*. Muscularis mucosæ. *f*. Mucous membrane, with vessels and part of a lymphoid nodule. *g*. Stratified epithelial lining. *h*. Mucous gland. *i*. Gland duct. *m'*. Striated muscular fibres cut across.

The *circular fibres* are continuous superiorly, on the posterior aspect, with the *Constrictor pharyngis inferior*; anteriorly, the uppermost are inserted into the lateral margins of the tendon of the two longitudinal fasciculi.*

The *muscular fibres* in the upper part of the *œsophagus* are of a red colour, and consist chiefly of the striped variety; but in the lower part they consist for the most part of involuntary fibres.

The *areolar or submucous coat* connects loosely the mucous and muscular coats. It contains the larger blood-vessels and nerves, as well as mucous glands.

The *mucous coat* is thick, of a reddish colour above, and pale below. It is disposed in longitudinal folds, which disappear on distension of the tube. It consists of (1) a layer of stratified squamous epithelium, lining the tube, (2) a layer of connective tissue, papillæ from which project into the epithelium, and (3) the *muscularis mucosæ*, a layer of longitudinally arranged non-striped muscular fibres. At the commencement of the *œsophagus* the *muscularis mucosæ* is absent, or only represented by a few scattered bundles; lower down it forms a considerable stratum.

The *œsophageal glands* are small compound racemose glands of the mucous type; they are lodged in the submucous tissue, and each opens upon the surface by a long duct.

Vessels and Nerves.—The arteries supplying the *œsophagus* are derived from the inferior thyreoid branch of the thyreocervical trunk, from the descending thoracic aorta, from the left gastric branch of the *cœliac artery*, and from the left inferior phrenic branch of the abdominal aorta. They have for the most part a longitudinal direction.

The nerves are derived from the *vagus nerves* and from the sympathetic trunks; they form a plexus, in which are groups of ganglion-cells, between the two layers of the muscular coat, and a second plexus in the submucous tissue.

Applied Anatomy.—The *œsophagus* may be obstructed by foreign bodies, and also by changes in its coats producing stricture, or by pressure on it from without by new growths or aneurysm, &c. The commoner forms of stricture are: (1) the fibrous, due to cicatrization following destruction of tissue, the result of swallowing boiling or corrosive fluids—here dilatation of the stricture may be carried out; and (2) malignant, usually epitheliomatous in its nature. This may be situated either at the upper end of the tube, opposite the cricoid cartilage, or at its lower end at the cardiac orifice, but is most commonly found in that part of the tube which is crossed by the left bronchus. If, in these cases, the patient is losing weight from insufficient nourishment, the operation of gastrostomy may be performed in order to avoid death from starvation; death, however, most commonly occurs from ulceration of the growth into the mediastinal cavity or air-passages. In cases of non-malignant stricture of the *œsophagus* it may be necessary to dilate the canal by a bougie, when it is of importance that the direction of the *œsophagus* and its relations to surrounding parts should be remembered. In malignant disease of the *œsophagus*, where its tissues have become softened from infiltration of the growth, the passage of a bougie is a very dangerous procedure, as a false passage may easily be made, and the instrument may pass into the mediastinal cavity or into one or other pleural cavity, or even into the pericardium.

In cases of destruction of the *œsophagus*, and consequent symptoms of stricture, produced by an aneurysm of some part of the aorta pressing upon this tube, the passage of a bougie will only hasten the fatal issue, and therefore it is essential that the presence of an aneurysm should be excluded before such an attempt be made in any form of *œsophageal* obstruction.

In passing a bougie the left forefinger should be introduced into the mouth, and the epiglottis felt for, care being taken not to throw the head too far backwards. The bougie is then to be passed beyond the finger until it touches the posterior wall of the pharynx. The patient is now asked to swallow, and at the moment of swallowing the bougie is passed gently onwards, any force being carefully avoided.

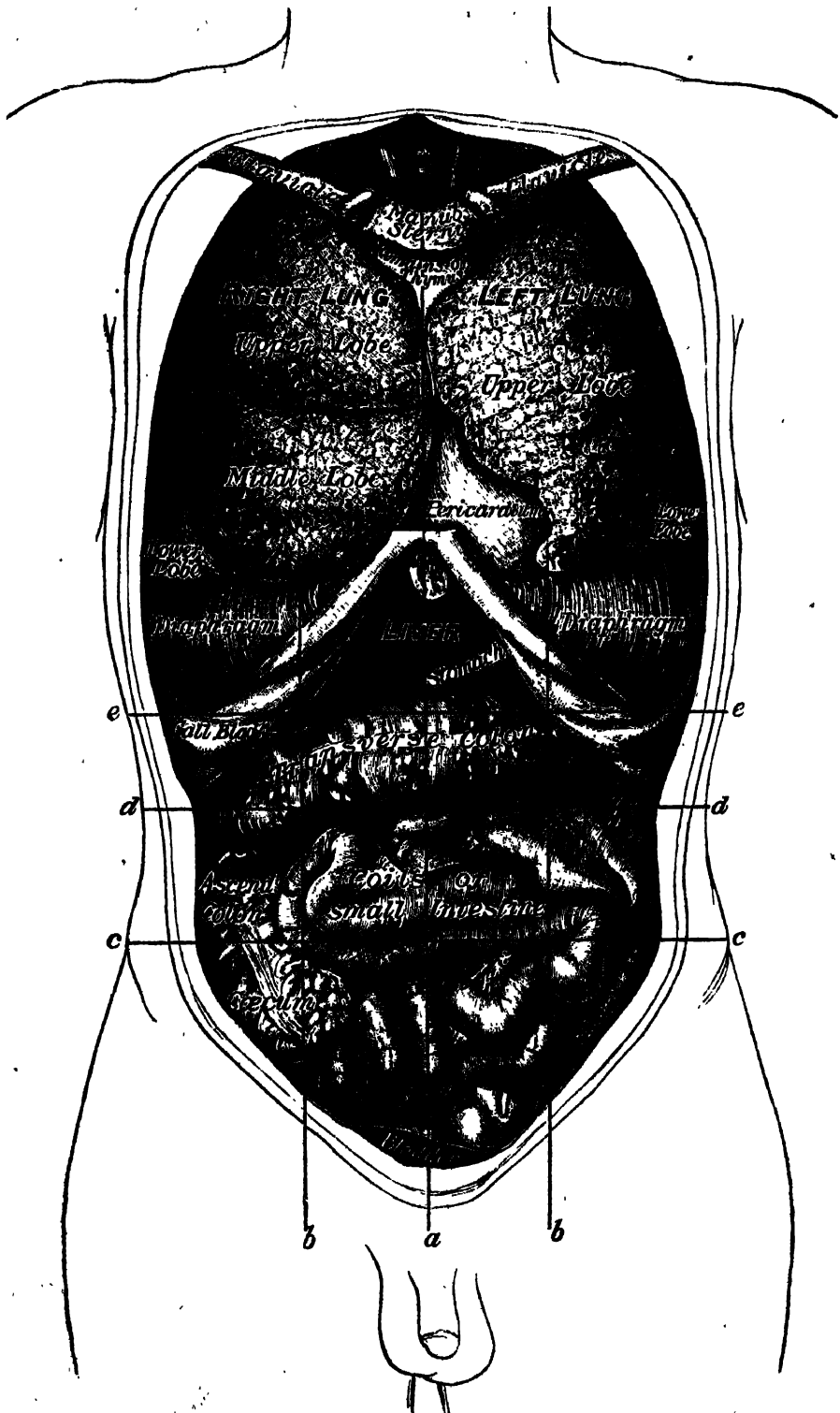
It occasionally happens that a foreign body becomes impacted in the *œsophagus*, and can neither be brought upwards nor moved downwards. When all ordinary means for its removal have failed, open operation by an incision in the neck is the only resource left. This, of course, can only be performed when the foreign body is not very low down. If it is allowed to remain, extensive inflammation and ulceration of the *œsophagus* may ensue, with the development of suppuration and cellulitis in the surrounding tissues.

THE ABDOMEN

The *abdomen* is the largest cavity in the body. The upper extremity is formed by the *Diaphragm*, which extends as a dome over the *abdomen*, so that the cavity extends high into the bony thorax, reaching on the right side, in the mammary line, to the upper border of the fifth rib; on the left side it falls below this level by about 2.5 cm. The lower extremity is formed by

* Abel, *Journal of Anatomy and Physiology*, vol. xlvii.

FIG. 997.—A front view of the thoracic and abdominal viscera.



The greater omentum has been removed.

a. Median plane. b b. Lateral planes. c c. Transtuberular plane. d d. Subcostal plane.
e e. Transpyloric plane.

the structures which clothe the inner surface of the bony pelvis, principally the Levator ani and Coccygeus on either side. These muscles are sometimes termed the *diaphragm of the pelvis*.*

In order to facilitate description the abdomen is artificially divided into two parts: an upper, larger part, the *abdomen proper*; and a lower, smaller part, the *pelvis*. These two parts are continuous with one another through the superior aperture of the lesser pelvis.

The *abdomen proper* differs from the other cavities of the body in being bounded for the most part by muscles and fasciæ, so that it can vary in capacity and shape according to the condition of the viscera which it contains.

It is bounded *in front* and *at the sides* by the abdominal and Iliacus muscles; *behind* by the vertebral column and the Psoas and Quadratus lumborum muscles; *above* by the Diaphragm; *below* by the plane of the superior aperture of the lesser pelvis. The muscles forming the boundaries of the cavity are lined upon their inner surfaces by a layer of fascia.

The Abdomen contains the greater part of the digestive tube; it also contains the liver, pancreas, spleen, kidneys, and suprarenal glands. Most of these structures, as well as the wall of the cavity in which they are contained, are more or less covered by an extensive and complicated serous membrane, the *peritoneum*.

Regions.—For convenience of description of the viscera, as well as of reference to the morbid conditions of the contained parts, the abdomen is divided into nine regions by imaginary planes, two horizontal and two sagittal, passing through the cavity, the edges of the planes being indicated by lines drawn on the surface of the body. Of the horizontal planes the upper or *transpyloric* plane of Addison is indicated by a line encircling the body at the level of a point midway between the jugular notch and the symphysis pubis, the lower by a line carried round the trunk at the level of a point midway between the transpyloric plane and the symphysis pubis. The latter is practically the *intertubercular plane* of Cunningham, who pointed out † that its level corresponds with the prominent and easily defined tubercle on the iliac crest about 5 cm. behind the anterior superior iliac spine. By means of these planes the abdomen is divided into three zones; each of these is further subdivided into three regions by the two sagittal planes, which are indicated on the surface by lines drawn vertically through points halfway between the anterior superior iliac spines and the symphysis pubis.‡

The middle region of the upper zone is the *epigastric*; and the lateral regions, the *right* and *left hypochondriac*. The central region of the middle zone is the *umbilical*; and the lateral regions are the *right* and *left lumbar*. The middle region of the lower zone is the *hypogastric*; and the lateral regions are the *right* and *left iliac* or *inguinal* (fig. 998).

The *pelvis* is that portion of the abdominal cavity which lies below and behind a plane passing through the promontory of the sacrum, the lineæ terminales of the hip-bones, and the pubic crests. It is bounded behind by the sacrum, coccyx, Piriformes, and the sacrospinous and sacrotuberous ligaments; in front and laterally by the ossa pubis and ischia and Obturatores interni; above it communicates with the abdomen proper; below it is closed by the Levatores ani and Coccygei and the urogenital diaphragm. The pelvis contains the urinary bladder, the sigmoid colon, the rectum, a few coils of the small intestine, and some of the generative organs.

When the anterior abdominal wall is removed, the viscera are partly exposed as follows: above and to the right side is the liver, situated chiefly under

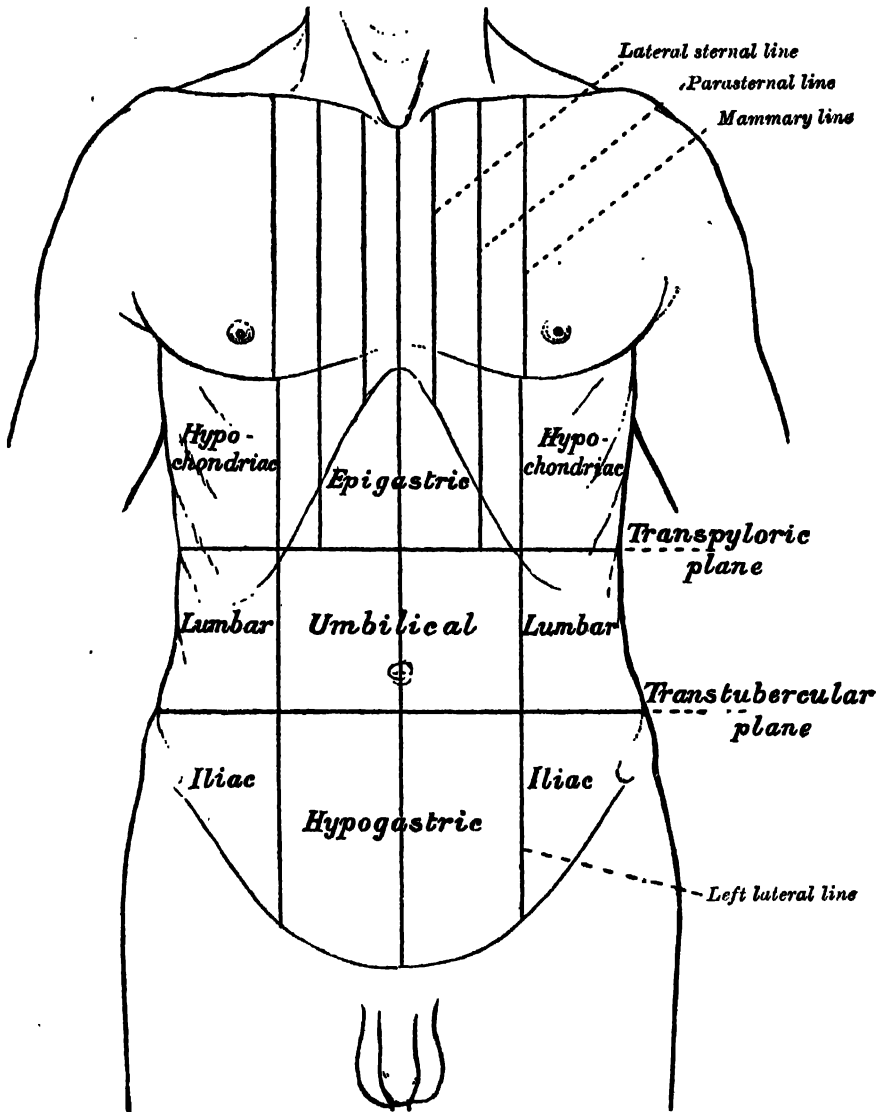
* Symington (*Journal of Anatomy and Physiology*, vol. xlvii.) found that in a spare male subject the height of the abdominopelvic cavity, in a medial sagittal section, was 42 cm.; and that the anteroposterior diameter was 7 cm. opposite the twelfth thoracic vertebra, 3 cm. opposite the umbilicus and 12 cm. opposite the lower part of the sacrum. In a vertical section 3.5 cm. to the left of the median plane, "the abdominopelvic cavity is somewhat hourglass-shaped, the constriction of the cavity being due to the psoas muscle which attains its maximum forward projection at about the level of the umbilicus." In a vertical section through the left lateral plane of the abdomen the cavity is triangular in outline, with its concave base above; in this plane the upper part of the cavity has a maximum anteroposterior diameter of nearly 13 cm.

† *Journal of Anatomy and Physiology*, vol. xxvii.

‡ *Ibid.*, vols. xxxiii, xxxiv, xxxv.

the shelter of the right ribs and their cartilages, but extending across the middle line and reaching for some distance below the level of the xiphoid process. To the left of the liver is the stomach, from the lower border of which an apron-like fold of peritoneum, the *greater omentum*, descends for a varying distance, and obscures, to a greater or lesser extent, the other viscera. Below it, however,

FIG. 998.—Surface lines on the front of the thorax and abdomen.



some of the coils of the small intestine can generally be seen, while in the right iliac region the caecum, and, in the left iliac region, the iliac portion of the descending colon, are partly exposed. The bladder occupies the anterior part of the pelvis, and, if distended, will project above the symphysis pubis; the rectum lies in the concavity of the sacrum, but is usually obscured by coils of the small intestine. The sigmoid colon may lie between the rectum and the bladder.

When the stomach is followed from left to right it is seen to be continuous with the first part of the small intestine, or duodenum, the point of continuity being marked by a thickened ring which indicates the position of the pyloric

valve. The duodenum passes towards the under surface of the liver, and then, curving downwards, is lost to sight. If, however, the greater omentum and transverse colon be thrown upwards over the chest, the inferior part of the duodenum will be observed passing across the vertebral column towards the left side, where it becomes continuous with the coils of the jejunum and ileum. These measure about six metres in length, and if followed downwards the ileum is seen to end in the right iliac fossa by opening into the cæcum, the commencement of the large intestine. From the cæcum the large intestine takes an arch-like course, passing at first upwards on the right side, then across the middle line and downwards on the left side, and forming respectively the ascending, transverse, and descending parts of the colon. In the pelvis it assumes the form of a loop, termed the sigmoid colon, and ends in the rectum.

The spleen lies behind the stomach in the left hypochondriac region, and may be in part exposed by pulling the stomach over towards the right side.

The glistening appearance of the deep surface of the abdominal wall and of the surfaces of the exposed viscera is due to the fact that the former is lined, and the latter are more or less completely covered, by a serous membrane, the *peritoneum*.

THE PERITONEUM

The *peritoneum* is the largest serous membrane in the body, and consists, in the male, of a closed sac, a part of which is applied against the abdominal parietes, while the remainder is reflected over the contained viscera. In the female the free ends of the uterine tubes open into the peritoneal cavity. The part which lines the parietes is named the *parietal* portion of the peritoneum; that which is reflected over the contained viscera constitutes the *visceral* portion of the peritoneum. The *free surface* of the membrane is smooth, covered by a layer of flattened endothelium, and lubricated by a small quantity of serous fluid. Hence the viscera can glide freely on the wall of the cavity or on one another with the least possible amount of friction. The *attached surface* is rough, being connected to the viscera and inner surface of the parietes by means of areolar tissue, termed the *subserous areolar tissue*. The parietal portion is loosely connected with the fascial lining of the abdomen and pelvis, but is more closely adherent to the under surface of the Diaphragm, and also in the middle line of the anterior abdominal wall.

The parietal and visceral layers of the peritoneum are in actual contact, but the potential space between them is named the *peritoneal cavity*. The peritoneal cavity gives off a large diverticulum, the *omental bursa*, which is situated behind the stomach and adjoining structures; the neck or communication between the cavity and the bursa is termed the *epiploic foramen* (foramen of Winslow). Formerly the main portion of the cavity was described as the greater sac, and the omental bursa as the lesser sac of the peritoneum.

The peritoneum differs from the other serous membranes of the body in presenting a much more complex arrangement, and one that can only be clearly understood by following the development of the digestive tube. The student therefore is advised to preface his study of the peritoneum by reading the chapter dealing with this subject (p. 128).

To trace the membrane from one viscus to another, and from the viscera to the parietes, it is necessary to follow its continuity in the vertical and horizontal directions, and it will be found simpler to describe the main portion of the cavity and the omental bursa separately.

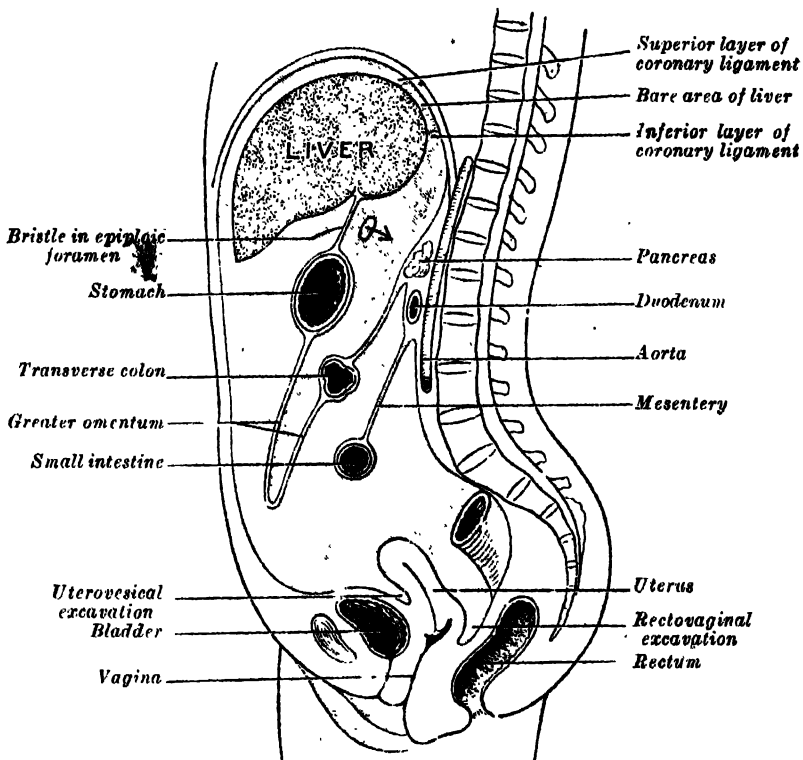
Vertical disposition of the main peritoneal cavity (greater sac) (fig. 999).—It is convenient to trace this from the back of the anterior abdominal wall at the level of the umbilicus. On following the peritoneum upwards from this level it is seen to be reflected around a fibrous cord, the *ligamentum teres*, or *obliterated umbilical vein*, which reaches from the umbilicus to the under surface of the liver. This reflection forms a somewhat triangular fold, the *falciform ligament of the liver*, attaching the upper and anterior surfaces of the liver to the Diaphragm and abdominal wall. With the exception of the line of attachment of this ligament the peritoneum covers the whole of the under surface of the anterior part of the Diaphragm, and is reflected from it on to the upper surface of the right lobe of the liver as the *superior layer of the coronary*

ligament, and on to the upper surface of the left lobe as the *superior layer of the left triangular ligament* of the liver. Covering the upper and anterior surfaces of the liver, it is continued round its sharp margin on to the under surface, where it presents the following relations: (a) It covers the under surface of the right lobe and is reflected from the back part of this on to the right suprarenal gland and upper extremity of the right kidney, forming in this situation the *inferior layer of the coronary ligament*; a special fold, the *hepatorenal ligament*, is frequently present between the inferior surface of the liver and the front of the kidney. From the kidney it is carried downwards to the duodenum and right colic flexure and medialwards in front of the inferior vena cava, where it is continuous with the posterior wall of the omental bursa. Between the two layers of the coronary ligament there is a large triangular surface of the liver devoid of peritoneal covering: this is named the *bare area* of the liver, and is attached to the Diaphragm by areolar tissue. Towards the right margin of the liver the two layers of the coronary ligament gradually approach each other, and ultimately fuse to form a small triangular fold connecting the right lobe of the liver to the Diaphragm, and named the *right triangular ligament* of the liver. The apex of the bare area corresponds with the point of meeting of the two layers of the coronary ligament, its base with the fossa for the inferior vena cava. (b) It covers the lower surface of the quadrate lobe, the under and lateral surfaces of the gall-bladder, and the under surface and posterior border of the left lobe; it is then reflected from the upper surface of the left lobe to the Diaphragm as the *inferior layer of the left triangular ligament*, and from the porta of the liver and the fossa for the ductus venosus to the lesser curvature of the stomach and the first 2.5 cm. of the duodenum as the anterior layer of the *hepatogastric* and *hepatoduodenal ligaments*, which together constitute the *lesser omentum*. If this layer of the lesser omentum be followed to the right it will be found to turn round the hepatic artery, bile-duct, and portal vein, and become continuous with the anterior wall of the omental bursa, forming a free folded edge of peritoneum. Traced downwards, the lesser omentum covers the anterosuperior surface of the stomach and the commencement of the duodenum, and is carried down into a large free fold, known as the *gastrocolic ligament* or *greater omentum*. Reaching the free margin of this fold, it is reflected upwards to cover the under and posterior surfaces of the transverse colon, and thence to the posterior abdominal wall as the inferior layer of the *transverse mesocolon*. It reaches the abdominal wall at the head and anterior border of the pancreas, is then carried down over the lower part of the head and over the inferior surface of the pancreas on the superior mesenteric vessels, and thence to the small intestine as the anterior layer of the *mesentery*. It encircles the intestine, and subsequently may be traced, as the posterior layer of the mesentery, upwards and backwards to the abdominal wall. From this it sweeps down over the aorta into the pelvis, where it invests the sigmoid (pelvic) colon, its reduplication forming the *sigmoid mesocolon* (pelvic mesocolon). Leaving first the sides and then the front of the rectum, it is reflected on to the seminal vesicles and the fundus of the urinary bladder, and after covering the upper surface of that viscus, is carried along the medial and lateral umbilical ligaments (fig. 1000) on to the back of the abdominal wall to the level from which a start was made.

Between the rectum and the bladder it forms, in the male, a pouch, the *rectovesical excavation*, the bottom of which is slightly below the level of the upper ends of the vesiculae seminales, and about 7.5 cm. from the orifice of the anus. When the bladder is distended, the peritoneum is carried up with it so that a considerable part of the anterior surface of the bladder lies directly against the abdominal wall without the intervention of peritoneal membrane. In the female the peritoneum is reflected from the rectum over the posterior vaginal fornix to the cervix and body of the uterus, forming the *recto-uterine excavation* or *pouch of Douglas*. It is continued over the intestinal surface and fundus of the uterus on to its vesical surface, which it covers as far as the junction of the body and neck of the uterus, and then to the bladder, forming here a second, but shallower, pouch, the *vesico-uterine excavation*. It is also reflected from the sides of the uterus to the lateral walls of the pelvis as two expanded folds, the *broad ligaments of the uterus*, in the free margin of each of which is the uterine tube.

Vertical disposition of the omental bursa (lesser sac) (fig. 999).—A start may be made in this case on the posterior abdominal wall at the anterior border of the pancreas. From this region the peritoneum may be followed upwards over the anterior surface of the pancreas on to the inferior surface of the Diaphragm, and thence on to the caudate lobe and caudate process of the liver to the fossa for the ductus venosus and the porta hepatis. Traced to the right, it is continuous over the inferior vena cava with the posterior wall of the main cavity. From the liver it is carried downwards to the lesser curvature of the stomach and the commencement of the duodenum as the

FIG. 999.—The vertical disposition of the peritoneum. (Main cavity, red; omental bursa, blue.)



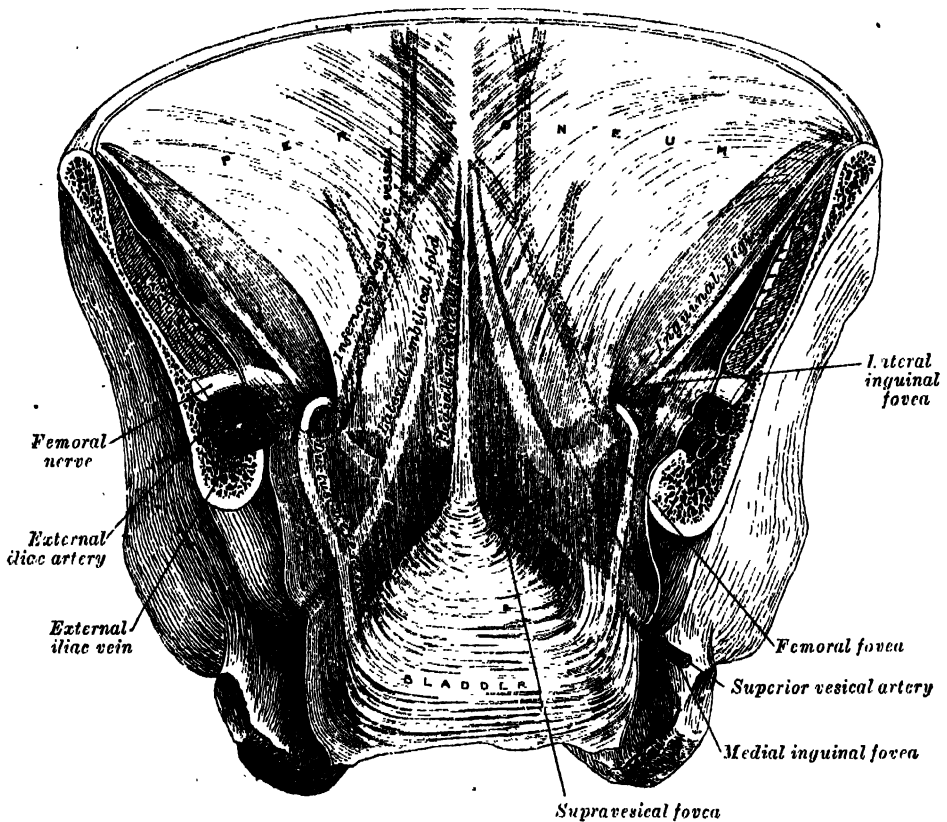
posterior layer of the lesser omentum, and is continuous on the right, round the hepatic artery, bile-duct, and portal vein, with the anterior layer of this omentum. The posterior layer of the lesser omentum is carried down as a covering for the postero-inferior surface of the stomach and commencement of the duodenum, and is continued downwards as the deep layer of the gastro-colic ligament or greater omentum. From the free margin of this fold it is reflected upwards to the anterior and superior surfaces of the transverse colon, and thence as the superior layer of the transverse mesocolon to the anterior border of the pancreas, the level from which a start was made. It will be seen that the loop formed by the wall of the omental bursa below the transverse colon follows, and is closely applied to, the deep surface of that formed by the peritoneum of the main cavity, and that the greater omentum or large fold of peritoneum which hangs in front of the small intestine therefore consists of four layers, two anterior and two posterior, separated by the potential cavity of the omental bursa. The transverse colon lies between the two posterior layers.

Horizontal disposition of the peritoneum.—Below the transverse colon the arrangement is simple, as it includes only the main cavity; above

the level of the transverse colon it is more complicated on account of the existence of the omental bursa. Below the transverse colon it may be considered in the two regions, viz. in the pelvis and in the abdomen proper.

(1) *In the pelvis.*—The peritoneum here follows closely the surfaces of the pelvic viscera and the inequalities of the pelvic walls, and presents important differences in the two sexes. (a) *In the male* (fig. 1001) it encircles the sigmoid colon, from which it is reflected to the posterior wall of the pelvis as a fold, the *sigmoid mesocolon*. It leaves the sides and, finally, the front of the rectum,

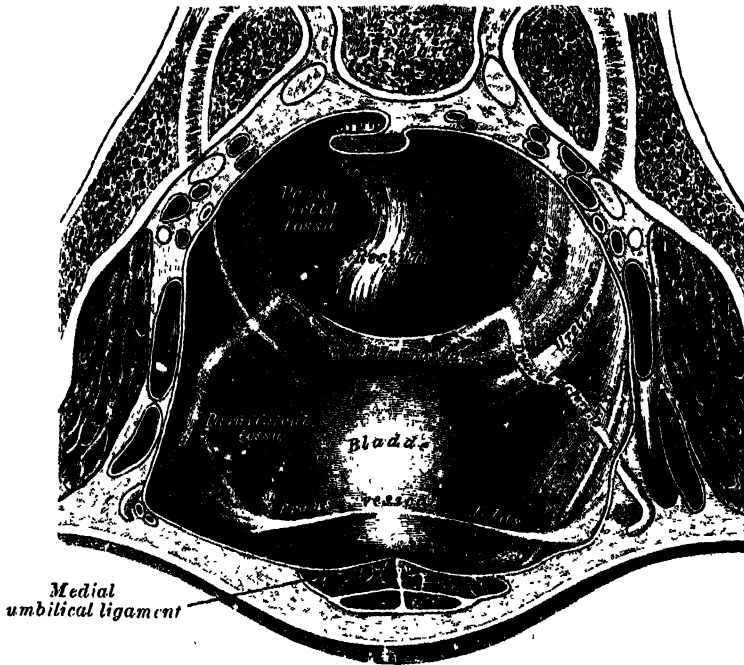
FIG. 1000.—A posterior view of the lower part of the anterior abdominal wall. The peritoneum is in place, and the various cords are shining through. (After Joessel.)



and is continued over the upper parts of the seminal vesicles on to the upper surface of the bladder; on either side of the rectum it forms a fossa, the *pararectal fossa*, which varies in size with the distension of the rectum. In front of the rectum the peritoneum forms the rectovesical excavation, which is limited laterally by peritoneal folds extending from the sides of the bladder to the rectum and sacrum. These folds are known, from their position, as the *rectovesical* or *sacrogenital folds*. The peritoneum of the anterior pelvic wall covers the superior surface of the bladder, and on either side of this viscus forms a depression, termed the *paravesical fossa*, which is limited laterally by the fold of peritoneum covering the ductus deferens. The size of this fossa is dependent on the state of distension of the bladder; when the bladder is empty, a variable fold of peritoneum, the *plica vesicalis transversa*, divides the fossa into two portions. On the peritoneum between the paravesical and pararectal fossae the only elevations are those produced by the ureters and the hypogastric vessels. (b) *In the female*, pararectal and paravesical

fossæ similar to these in the male are present: the lateral limit of the paravesical fossa is the peritoneum investing the round ligament of the uterus. The rectovesical excavation is, however, divided by the uterus and vagina into a small anterior vesico-uterine and a large, deep, posterior recto-uterine excavation. The sacrogenital folds form the margins of the latter, and are continued on to the back of the uterus and the posterior fornix of the vagina as a transverse fold, the *torus uterinus*. The *broad ligaments* extend from the sides of the uterus to the lateral walls of the pelvis; they contain in their free margins the uterine tubes, and in their posterior layers the ovaries. Below, the broad ligaments are continuous with the peritoneum on the lateral walls of the pelvis. On the lateral pelvic wall behind the attachment of the broad

FIG. 1001.—The peritoneum of the male pelvis. (Dixon and Birmingham.)



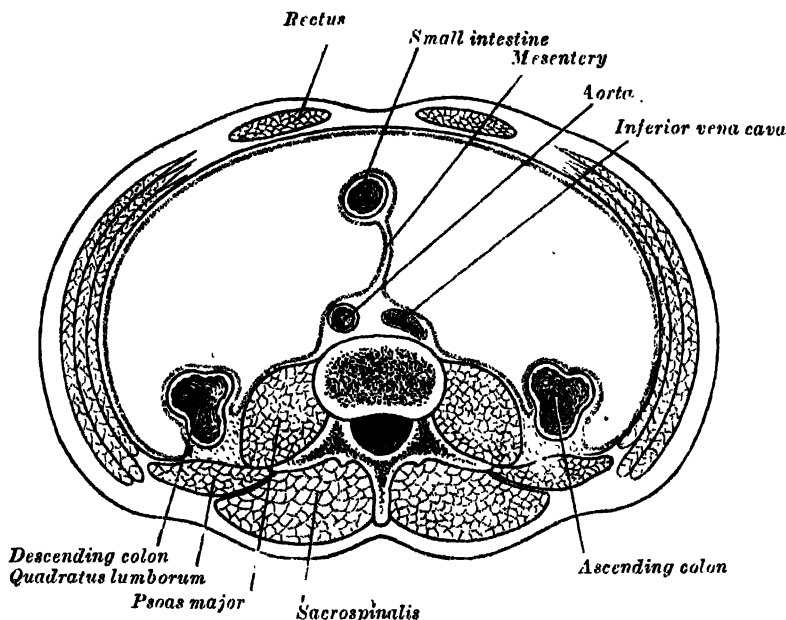
ligament, in the angle between the elevations produced by the obliterated hypogastric artery and the ureter, is a slight fossa, the *ovarian fossa*, in which the ovary normally lies.

(2) *In the lower abdomen* (fig. 1002).—Starting from the linea alba, below the level of the transverse colon, and tracing the continuity of the peritoneum in a horizontal direction to the right, the membrane covers the inner surface of the abdominal wall almost as far as the lateral border of the Quadratus lumborum; it encloses the cæcum and vermiform process, and is reflected over the sides and front of the ascending colon; it may then be traced over the duodenum, Psoas major, and inferior vena cava towards the middle-line, whence it passes along the mesenteric vessels to invest the small intestine, and back again to the large vessels in front of the vertebral column, forming the *mesentery*, between the layers of which are contained the mesenteric blood-vessels, nerves, lacteals, and lymph-glands. It is then continued over the left Psoas major; it covers the sides and front of the descending colon, and, reaching the abdominal wall, is carried on it to the middle line.

(3) *In the upper abdomen* (fig. 1003).—Above the transverse colon the omental bursa is superadded to the general sac, and the communication of the two cavities with one another through the epiploic foramen can be demonstrated.

(a) *Main cavity*.—Commencing on the posterior abdominal wall at the inferior vena cava, the peritoneum may be followed to the right over the front of the right suprarenal gland and upper part of the right kidney on to the anterolateral abdominal wall. From the middle line of the anterior wall a backwardly directed fold encircles the obliterated umbilical vein and forms the falciform ligament of the liver. Continuing to the left, the peritoneum lines the anterolateral abdominal wall and covers the lateral part of the front of the left kidney, and is reflected to the posterior border of the hilum of the spleen as the posterior layer of the *phrenicocolic ligament* (lienorenal ligament). It can be traced round the surface of the spleen to the front of the hilum, and thence to the cardiac end of the greater curvature of the stomach as the anterior

FIG. 1002.—The horizontal disposition of the peritoneum in the lower part of the abdomen.



layer of the *gastrolieal ligament* (gastrosplenic omentum). It covers the anterosuperior surface of the stomach and commencement of the duodenum, and extends up from the lesser curvature of the stomach to the liver as the anterior layer of the lesser omentum.

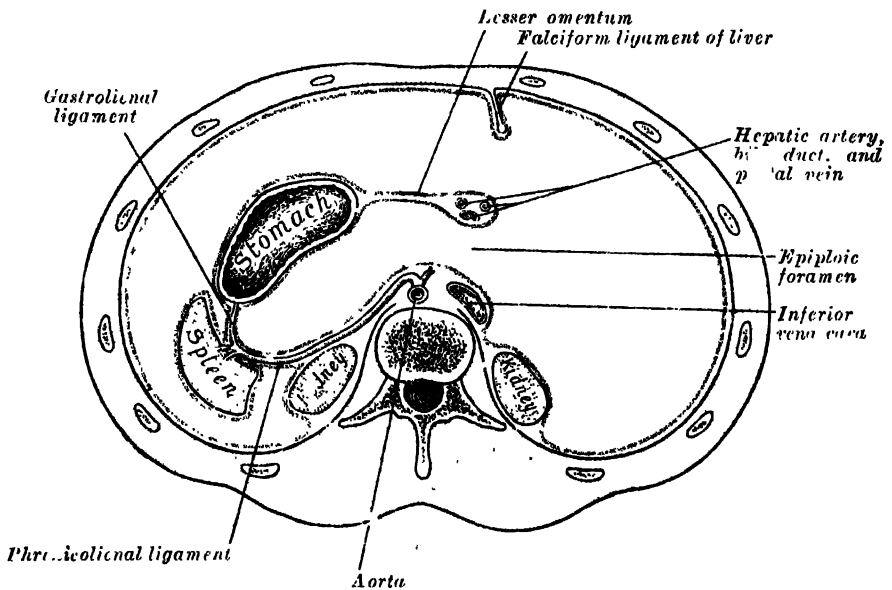
(b) *Omental bursa*.—On the posterior abdominal wall the peritoneum of the general cavity is continuous with that of the omental bursa in front of the inferior vena cava. Starting from here, the bursa may be traced across the aorta and over the medial part of the front of the left kidney and Diaphragm to the hilum of the spleen as the anterior layer of the phrenicocolic ligament. From the spleen it is reflected to the stomach as the posterior layer of the gastrolieal ligament. It covers the postero-inferior surface of the stomach and commencement of the duodenum, and extends upwards to the liver as the posterior layer of the lesser omentum; the right margin of this layer is continuous round the hepatic artery, bile-duct, and portal vein with the wall of the main cavity. The lienal vessels run between the two layers of the phrenicocolic ligament, and the short gastric and left gastro-epiploic vessels between the two layers of the gastrolieal ligament.

The *epiploic foramen* (foramen of Winslow) (fig. 1076) is the communication between the main cavity and the omental bursa. It is bounded *in front* by the free border of the lesser omentum, with the common bile-duct, hepatic artery, and portal vein between its two layers; *behind* by the peritoneum covering the inferior vena cava; *above* by the peritoneum on the caudate

process of the liver; and *below* by the peritoneum covering the commencement of the duodenum and the hepatic artery, the latter passing forwards below the foramen before ascending between the two layers of the lesser omentum.

The boundaries and the extent of the omental bursa will now be evident. It is bounded *in front*, from above downwards, by the caudate lobe of the liver, the lesser omentum, the stomach, and the two anterior layers of the greater omentum. *Behind* it is limited, from below upwards, by the two posterior layers of the greater omentum, the transverse colon, and the ascending layer of the transverse mesocolon, the anterior surface of the pancreas, the left suprarenal gland, and the upper end of the left kidney. To the right of the oesophageal opening of the stomach it is bounded by that part of the Diaphragm which supports the caudate lobe of the liver and by the aorta and the inferior vena cava. Laterally, the bursa extends from the epiploic foramen to the spleen, where it is limited by the phrenocolical and gastrolenal ligaments.

FIG. 1003.—The horizontal disposition of the peritoneum in the upper part of the abdomen.



The omental bursa consists of a vestibule and three recesses, a superior, a middle and an inferior.

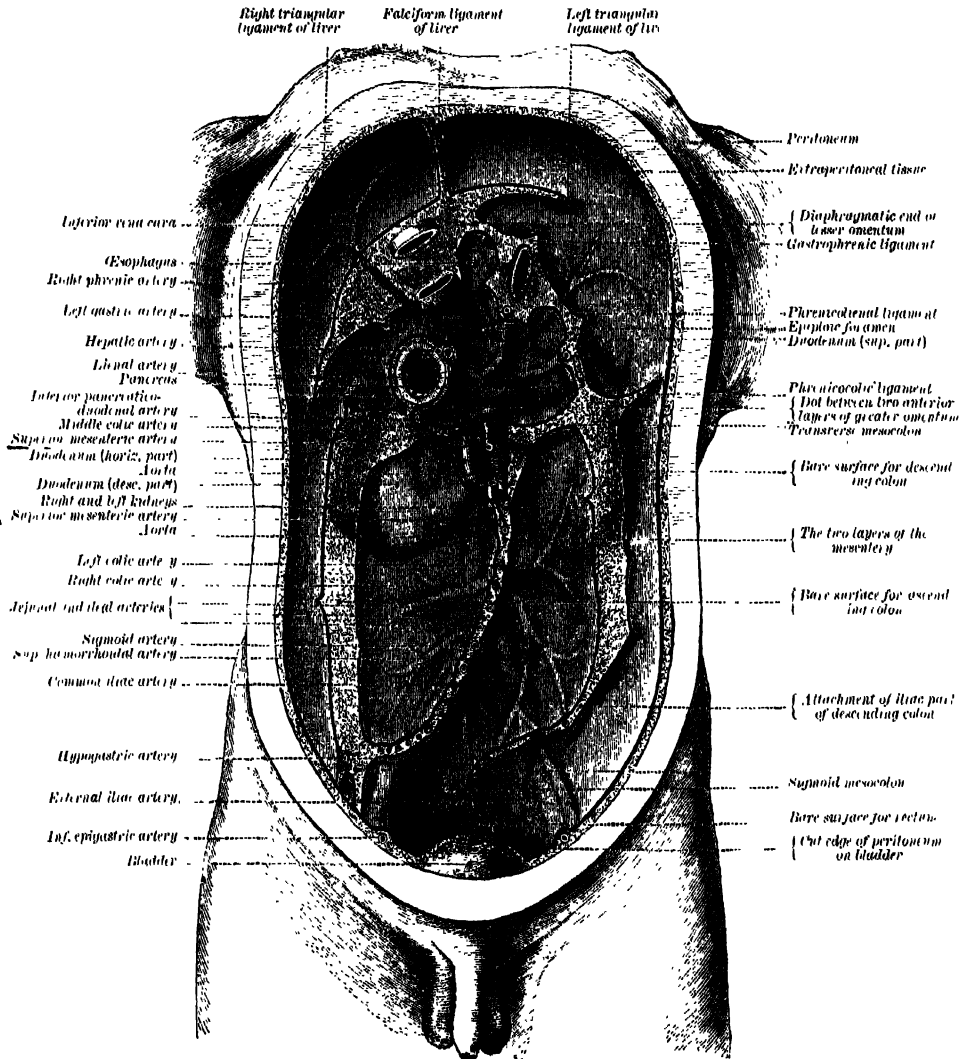
The *vestibule* is a narrow channel situated immediately to the left of the epiploic foramen, below the caudate process of the liver, above the head of the pancreas and superior part of the duodenum, and behind the hepatoduodenal ligament (p. 1094). The hepatic artery, portal vein, and common bile-duct pass forwards below the vestibule and then ascend between the two layers of the hepatoduodenal ligament. The *superior* recess extends upwards from the vestibule behind the porta hepatis and the caudate lobe of the liver, and in front of the Diaphragm and aorta. The *middle* recess, a small but variable pouch, descends between the lesser omentum and the pancreas. The vestibule and the superior and middle recesses together constitute the *bursa omenti minoris*. The *inferior* recess, or *bursa omenti majoris*, lies behind the stomach and extends as a large *lienal recess* between the stomach and the spleen. In the foetus the inferior recess reaches as low as the free margin of the greater omentum, but in the adult the vertical extent of the recess is much more limited owing to adhesions between the layers of the greater omentum.

The vestibule and the inferior recess may be shut off from one another by a complete *septum bursarum*, but in most cases they communicate through a rounded opening, the *foramen bursae omenti majoris*. This opening is limited

posteriorly by the *gastropancreatic ligament*, a sickle-shaped fold of peritoneum which encloses the left gastric artery, and extends from the tuber omentale of the pancreas to the back of the fundus of the stomach.

Crymble* states that two gastropancreatic ligaments can frequently be distinguished, viz. a *vertical* fold attaching the posterior border of the lesser curvature of the stomach to the Diaphragm and pancreas, and a *horizontal* fold between the pyloric part of the

FIG. 1004.—A diagram devised by Delépine to show the lines along which the peritoneum leaves the wall of the abdomen to invest the viscera.



stomach and the pancreas. He gives as the boundaries of the foramen hursae omenti majoris, the lesser curvature of the stomach, the pancreas and the gastropancreatic ligaments. He found these ligaments absent in seven out of thirty five subjects.

During a considerable part of foetal life the transverse colon is suspended from the posterior abdominal wall by a mesentery of its own, the two posterior layers of the greater omentum passing at this stage in front of the colon (fig. 208). This condition occasionally persists throughout life, but as a rule adhesion occurs between the mesentery of the transverse colon and the posterior layer

* *Journal of Anatomy and Physiology*, vol. xlvii.

of the greater omentum, with the result that the colon appears to receive its peritoneal covering by the splitting of the two posterior layers of the latter fold. In the adult the ommental bursa intervenes between the stomach and the structures on which that viscus lies, and performs therefore the functions of a serous bursa for the stomach.

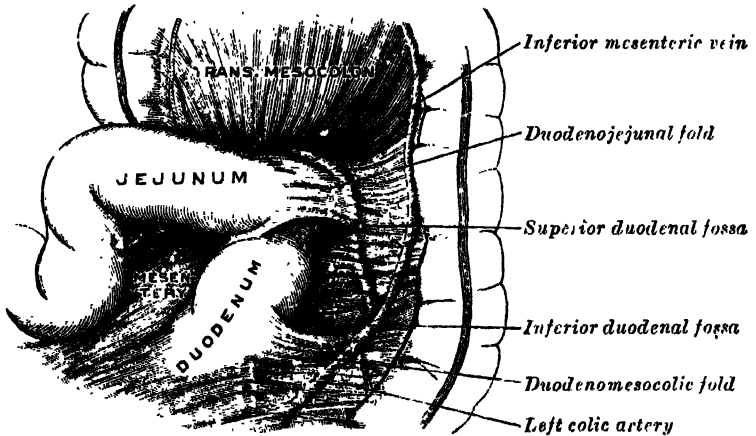
Numerous peritoneal folds extend between the various organs or connect them to the parietes; they serve to hold the viscera in position, and, at the same time, enclose the vessels and nerves proceeding to them. They are grouped as ligaments, omenta, and mesenteries.

The ligaments will be described with their respective organs.

There are two omenta, the lesser and the greater.

The *lesser omentum* is the fold which extends to the liver from the lesser curvature of the stomach and the commencement of the duodenum. It is continuous with the two layers of peritoneum which cover respectively the anterosuperior and postero-inferior surfaces of the stomach and first part of the duodenum. When these two layers reach the lesser curvature of the stomach and the upper border of the duodenum, they unite and ascend as

FIG. 1005.—The superior and inferior duodenal fossæ. (Poirier and Charpy.)



a double fold to the porta hepatis; to the left of the porta hepatis the fold is attached to the bottom of the fossa for the ductus venosus, along which it is carried to the Diaphragm, where the two layers separate to embrace the end of the œsophagus. At the right border of the omentum the two layers are continuous, and form a free margin which constitutes the anterior boundary of the epiploic foramen. The portion of the lesser omentum extending between the liver and stomach is termed the *hepatogastric ligament*, while that between the liver and duodenum is the *hepatoduodenal ligament*. Between the two layers of the lesser omentum, close to the right free margin, are the hepatic artery, the common bile-duct, the portal vein, lymphatics, and the hepatic plexus of nerves—all these structures being enclosed in a *fibrous capsule* (Glisson's capsule). The right and left gastric arteries run between the layers of the lesser omentum, where these are attached to the stomach.

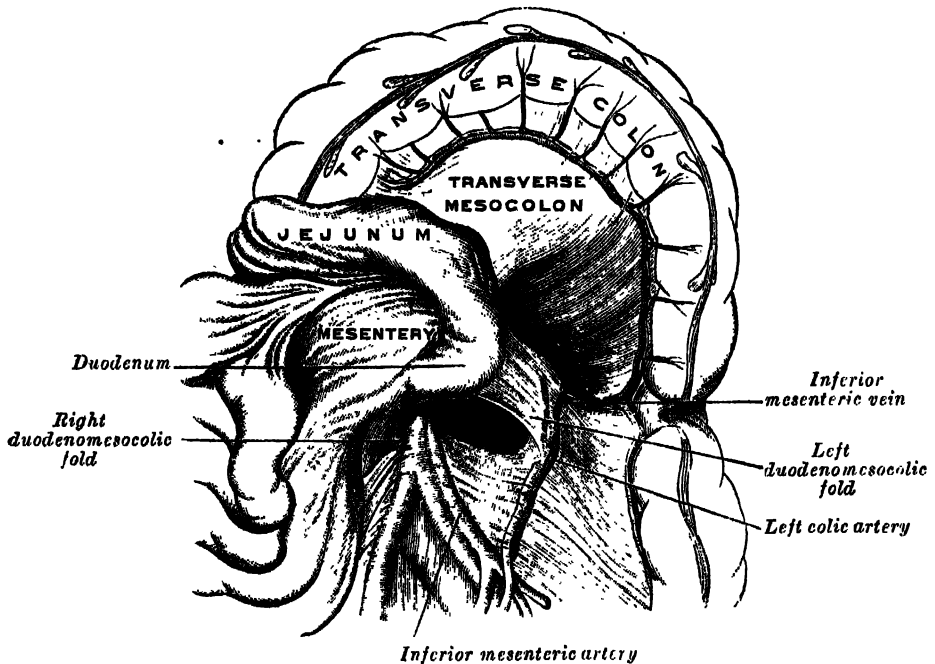
The *greater omentum* is the largest peritoneal fold. It consists of a double sheet of peritoneum, folded on itself so that it is made up of four layers. The two layers which descend from the stomach and commencement of the duodenum pass in front of the small intestines, sometimes as low down as the pelvis; they then turn upon themselves, and ascend again as far as the transverse colon, where they separate and enclose that part of the intestine. These individual layers may be easily demonstrated in the young subject, but in the adult they are more or less inseparably blended. The left border of the greater omentum is continuous with the gastroligament; its right border extends as far as the commencement of the duodenum. The

greater omentum is usually thin, presents a cribriform appearance, and always contains some adipose tissue, which in fat people accumulates in considerable quantity. Between its two anterior layers, a short distance from the greater curvature of the stomach, is the anastomosis between the right and left gastro-epiploic vessels.

The *mesenteries* are: the mesentery (mesentery proper), the mesenteriole of the vermiform process, the transverse mesocolon, and the sigmoid mesocolon. In addition to these there are sometimes an ascending and a descending mesocolon.

The *mesentery* is a broad, fan-shaped fold of peritoneum connecting the convolutions of the jejunum and ileum with the posterior wall of the abdomen. Its *root*—the border connected with the structures in front of the vertebral column—is narrow, about 15 cm. long, and is directed obliquely from the

FIG. 1006.—The duodenojejunal fossa. (Poirier and Charpy.)



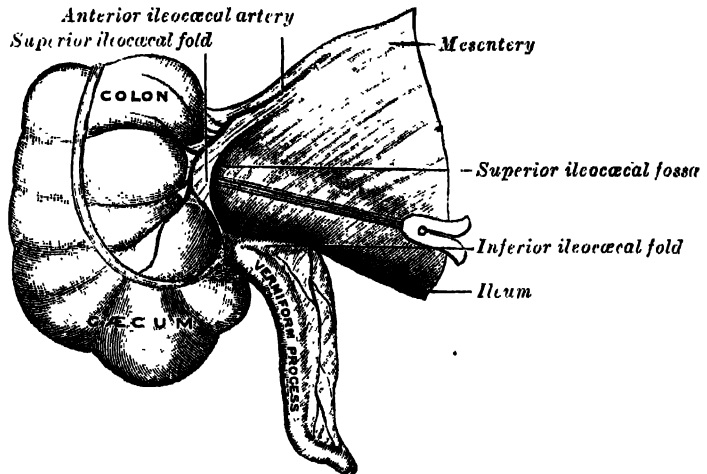
duodenojejunal flexure at the left side of the second lumbar vertebra to the right sacro-iliac articulation (fig. 1004). Its intestinal border is nearly 7 metres long; and here the two layers separate to enclose the intestine and form its peritoneal coat. It is short above, but lengthens rapidly to about 20 cm., and is thrown into numerous plaits or folds. It suspends the small intestine, and contains between its layers the jejunal and ileal branches of the superior mesenteric artery, with their accompanying veins and plexuses of nerves, the lacteal vessels, the mesenteric lymph-glands, and a varying amount of fatty tissue.

The *mesenteriole of the vermiform process* is attached to the back of the lower end of the mesentery, close to the ilcoecal junction, and passes behind the terminal part of the ileum to clothe the appendix. Between its layers are the blood-vessels, nerves and lymphatic vessels of the appendix together with a lymph-gland.

The *transverse mesocolon* is a broad fold connecting the transverse colon to the posterior wall of the abdomen. It is continuous with the two posterior layers of the greater omentum, which, after separating to surround the transverse colon, join behind it, and are continued to the vertebral column, where they diverge in front of the anterior border of the pancreas. This fold contains between its layers the vessels which supply the transverse colon.

The *sigmoid mesocolon* is a fold of peritoneum which retains the sigmoid colon in connexion with the pelvic wall. Its line of attachment forms a V-shaped curve, the apex of the curve being placed near the point of division of the left common iliac artery. The curve begins on the medial side of the left Psoas major, and runs upwards and backwards to the apex, from which

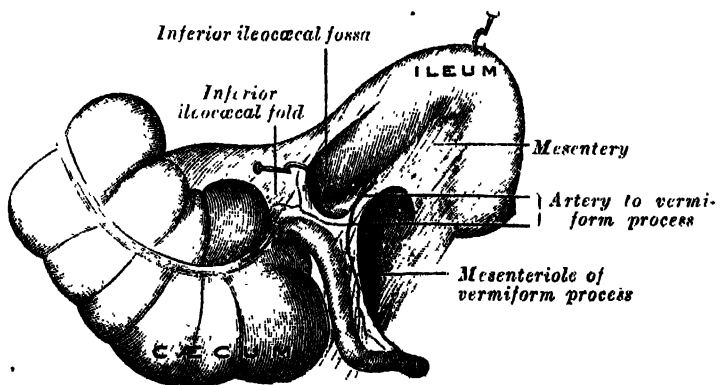
Fig. 1007.—Superior ilioecæal fossa. (Poirier and Charpy.)



it bends sharply downwards, and ends in the median plane at the level of the third sacral vertebra. The sigmoid and superior hæmorrhoidal vessels run between the two layers of this fold.

In most cases the peritoneum covers only the front and sides of the ascending and descending parts of the colon. Sometimes, however, these are surrounded by peritoneum and attached to the posterior abdominal wall by an ascending and a descending mesocolon respectively. A fold of peritoneum, the *phrenicocolic ligament*, is continued from the left colic flexure to the Diaphragm opposite

FIG. 1008.—Inferior ileocæcal fossa. The cæcum and ascending colon have been drawn lateralwards and downwards, the ileum upwards and backwards, and the vermiform process downwards. (Poirier and Charpy.)



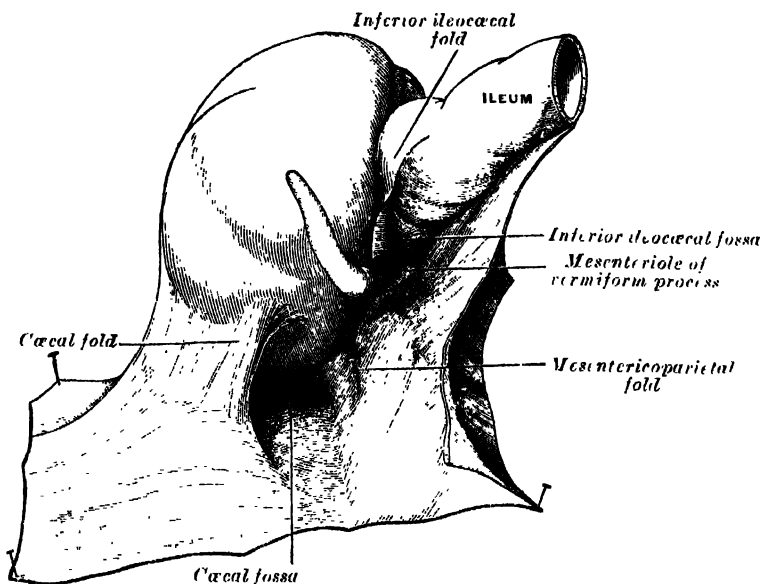
the tenth and eleventh ribs; it passes below and serves to support the spleen, and therefore has received the name of *sustentaculum lienis*.

The *appendices epiploicæ* are small pouches of the peritoneum filled with fat and situated along the colon and upper part of the rectum. They are chiefly appended to the transverse and sigmoid parts of the colon.

Peritoneal recesses or fossæ.—In certain parts of the abdominal cavity there are recesses of peritoneum forming culs-de-sac or pouches, which are of surgical interest in connexion with the possibility of the occurrence of 'retro-peritoneal' herniæ. The largest of these is the omental bursa (already described), but several others, of smaller size, require mention, and may be divided into three groups, viz.: duodenal, cæcal, and intersigmoid.

1. *Duodenal fossæ* (figs. 1005, 1006).—Three are fairly constant, viz.: (a) The *inferior duodenal fossa*, present in from 70 to 75 per cent. of cases, is situated opposite the third lumbar vertebra, on the left side of the ascending portion of the duodenum. Its opening is directed upwards, and is bounded by a thin sharp fold of peritoneum with a concave margin, called the *duodeno-mesocolic fold*. The tip of the index finger introduced into the fossa under

FIG. 1009.—The cæcal fossa. The ileum and cæcum are drawn backwards and upwards. (Souligoux.)



the fold passes some little distance behind the ascending portion of the duodenum. (b) The *superior duodenal fossa*, present in from 40 to 50 per cent. of cases, often co-exists with the inferior, and its orifice looks downwards. It lies on the left of the ascending portion of the duodenum, in front of the second lumbar vertebra, and behind a sickle-shaped fold of peritoneum, the *duodenojejunal fold*, and has a depth of about 2 cm. (c) The *duodenojejunal fossa* exists in from 15 to 20 per cent. of cases, but has never yet been found in conjunction with the other forms of duodenal fossæ; it can be seen by pulling the jejunum downwards and to the right, after the transverse colon has been pulled upwards. It is bounded above by the pancreas, to the right by the aorta, and to the left by the kidney; beneath is the left renal vein. It has a depth of from 2 cm. to 3 cm., and its orifice, directed downwards and to the right, is nearly circular and will admit the tip of the little finger.

2. *Cæcal fossæ.*—There are three principal pouches or recesses in the neighbourhood of the cæcum: (a) The *superior ileocaecal fossa* (fig. 1007) is formed by a fold of peritoneum, arching over the branch of the ileocolic artery which supplies the ileocolic junction. The fossa is a narrow chink situated between the mesentery of the small intestine, the ileum, and the small portion of the cæcum behind. (b) The *inferior ileocaecal fossa* (fig. 1008) is situated behind the angle of junction of the ileum and cæcum. It is formed by the *inferior*

ileocaecal fold of peritoneum (bloodless fold of Treves), the upper border of which is fixed to the ileum, opposite its mesenteric attachment, while the lower border, passing over the ileocaecal junction, joins the mesenteriole of the vermiform process, and sometimes the process itself. Between this fold and the mesenteriole of the vermiform process is the inferior ileocaecal fossa. It is bounded above by the posterior surface of the ileum and the mesentery; in front and below by the ileocaecal fold, and behind by the upper part of the mesenteriole of the vermiform process. (c) The *cæcal fossa* (fig. 1009) is situated immediately behind the cæcum, which has to be raised to bring it into view. It varies much in size and extent. In some cases it is sufficiently large to admit the index finger, and extends upwards behind the ascending colon in the direction of the kidney; in others it is merely a shallow depression. It is bounded on the right by the cæcal fold, which is attached by one edge to the abdominal wall from the lower border of the kidney to the iliac fossa, and by the other to the posterolateral aspect of the colon. In some instances additional fossæ, the *retrocæcal fossæ*, are present.

3. The *intersigmoid fossa* is constant in the foetus and during infancy, but disappears in a certain percentage of cases as age advances. Upon drawing the sigmoid colon upwards, the left surface of the sigmoid mesocolon is exposed, and on it will be seen a funnel-shaped recess of the peritoneum, lying on the external iliac vessels, in the interspace between the Psoas and Iliacus muscles. This is the orifice leading to the intersigmoid fossa, which lies behind the sigmoid mesocolon, and in front of the parietal peritoneum. The fossa varies in size; in some instances it is a mere dimple, in others it will admit the whole of the index finger.

Applied Anatomy.—Any of these fossæ may be the site of a 'retroperitoneal' hernia. The cæcal fossæ are of especial interest, because hernia of the vermiform process frequently takes place in one of them, and it may there become strangulated. The presence of these pouches also explains the course which pus has been known to take in cases of perforation of the vermiform process, where it travels upwards behind the ascending colon as far as the Diaphragm.*

THE STOMACH (VENTRICULUS)

The **stomach** is the most dilated part of the digestive tube, and is situated between the end of the œsophagus and the beginning of the small intestine. It lies in the epigastric, umbilical, and left hypochondriac regions of the abdomen, and occupies a recess bounded by the upper abdominal viscera, and completed in front and on the left side by the anterior abdominal wall and the Diaphragm.

The *shape and position* of the stomach are so greatly modified by changes within itself and in the surrounding viscera that no one form can be described as typical. The chief modifications are determined by (1) the amount of the stomach contents, (2) the stage which the digestive process has reached, (3) the degree of development of the gastric musculature, and (4) the condition of the adjacent intestines. It is, however, possible by comparing a series of stomachs, which have been hardened in situ, to determine certain markings more or less common to all (fig. 1010).

The stomach presents two openings, two borders or curvatures, and two surfaces.

Openings.—The opening by which the œsophagus communicates with the stomach is known as the *cardiac orifice*, and is situated on the left of the middle line at the level of the tenth thoracic vertebra. The short abdominal portion of the œsophagus (*antrum cardiacum*) is conical in shape and curved sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach. The right margin of the œsophagus is continuous with the lesser curvature of the stomach, while the left margin joins the greater curvature at an acute angle, termed the *incisura cardiaca*.

The *pyloric orifice* communicates with the duodenum, and its position is usually indicated on the surface of the stomach by a circular groove, the

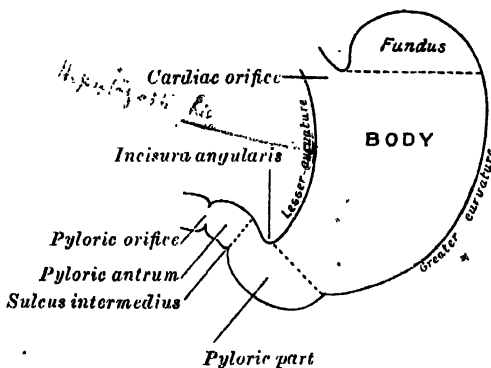
* On the anatomy of these fossæ, see the *Arrie and Gale Lectures* by Maynard, 1890.

duodenopyloric constriction. This orifice lies to the right of the middle line at the level of the upper border of the first lumbar vertebra.

Curvatures.—The *lesser curvature*, extending between the cardiac and pyloric orifices, forms the right or posterior border of the stomach. It descends as a continuation of the right margin of the oesophagus in front of the fibres of the right crus of the Diaphragm, and then, turning to the right, it crosses the first lumbar vertebra and ends at the pylorus. Nearer its pyloric than its cardiac end is a well-marked notch, the *incisura angularis*, which varies somewhat in position with the state of distension of the viscus; it serves to separate the stomach into a right and a left portion. The lesser curvature gives attachment to the two layers of the hepatogastric ligament, and between these two layers are the right and left gastric arteries.

The greater curvature is directed mainly forwards, and is four or five times as long as the lesser curvature. Starting from the cardiac orifice at the *incisura cardiaca*, it forms an arch backwards, upwards, and to the left; the highest point of the convexity is on a level with the sixth left costal cartilage. From this level it may be followed downwards and forwards, with a slight convexity to the left as low as the cartilage of the ninth rib; it then turns to the right,

FIG. 1010.—An outline of the stomach, showing its anatomical landmarks.



to end at the pylorus. Directly opposite the *incisura angularis* of the lesser curvature the greater curvature presents a dilatation, which is the left extremity of the *pyloric part*; this dilatation is limited on the right by a slight groove, the *sulcus intermedius*, which is about 2.5 cm. from the duodenopyloric constriction. The portion between the sulcus intermedius and the duodenopyloric constriction is termed the *pyloric antrum*. At its commencement the greater curvature is covered by peritoneum continuous with that on the front of the stomach. The left part of the curvature gives attachment to the gastrolenal ligament, while to its anterior portion are attached the two layers of the greater omentum, separated from each other by the gastro-epiploic vessels.

Surfaces.—When the stomach is in the contracted condition, its surfaces are directed upwards and downwards respectively, but when the viscus is distended they look forwards and backwards. They may therefore be described as anterosuperior and postero-inferior.

Anterosuperior surface.—The left half of this surface is in contact with the Diaphragm, which separates it from the base of the left lung, the pericardium, and the seventh, eighth, and ninth ribs and intercostal spaces of the left side. The right half is in relation with the left and quadrate lobes of the liver and with the anterior abdominal wall. When the stomach is empty, the transverse colon may lie on the front part of this surface. The whole surface is covered by peritoneum.

The postero-inferior surface is in relation with the Diaphragm, the spleen, the left suprarenal gland, the upper part of the front of the left kidney, the anterior surface of the pancreas, the left colic flexure, and the upper layer of the transverse mesocolon. These structures form a shallow bed, the *stomach*

bed, on which the viscus rests. The transverse mesocolon separates the stomach from the duodenojejunal flexure and small intestine. The postero-inferior surface is covered by peritoneum, except over a small area close to the cardiac orifice; this area is limited by the lines of attachment of the *gastrophrenic ligament*, and lies in apposition with the Diaphragm, and frequently with the upper portion of the left suprarenal gland.

FIG. 1011.—A diagram showing the shape and position of the empty stomach. Erect posture. (After Hertz.)

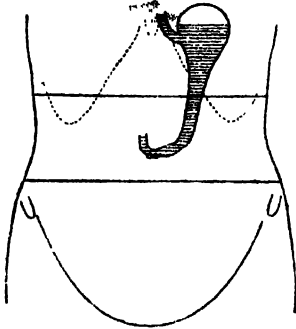


FIG. 1012.—A diagram showing the shape and position of the distended stomach. Erect posture. (After Hertz.)

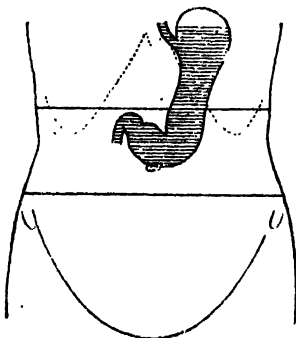
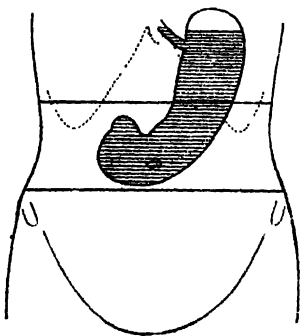


FIG. 1013.—A diagram showing the shape and position of the moderately filled stomach. Erect posture. (After Hertz.)



Component parts of the stomach.—A plane passing through the incisura angularis on the lesser curvature and the left limit of the opposed dilatation on the greater curvature divides the stomach into a left portion or *body* and a right or *pyloric portion*. The upper portion of the body is known as the *fundus*, and is marked off from the remainder of the body by a plane passing horizontally through the cardiac orifice. The pyloric portion is divided by a plane through the sulcus intermedius at right angles to the long axis of this portion; the part to the right of this plane is the *pyloric antrum* (fig. 1010).

By means of x-rays the form and position of the stomach can be studied in the living subject after the administration of a meal containing bismuth. During the process of digestion, it will be found divided by a muscular constriction into a large dilated left portion, and a narrow contracted tubular right portion. The constriction is in the body of the stomach, and does not follow any of the anatomical landmarks; indeed, it shifts gradually towards the left as digestion progresses, i.e. more of the body is gradually absorbed into the tubular part. The position of the stomach varies with the posture, with the amount of the stomach contents, and with the condition of the intestines on which it rests (figs. 1011 to 1013). In the erect posture the empty stomach is somewhat J-shaped; the part above the cardiac orifice is usually distended with gas; the pylorus descends to the level of the second lumbar vertebra, and the most dependent part of the stomach is at the level of the umbilicus. Variation in the amount of its contents affects mainly the cardiac portion, the pyloric portion remaining in a more or less contracted condition during the process of digestion. As the stomach fills it tends to expand forwards and downwards in the direction of least resistance, but when this is interfered with by a distended condition of the colon or intestines the fundus presses upwards on the liver and Diaphragm and gives rise to the feelings of oppression and palpitation complained of in such cases. His* and Cunningham† have shown by hardening the viscera *in situ* that the contracted stomach has a sickle shape, the fundus looking directly backwards. The surfaces are directed upwards and downwards, the upper surface having, however, a gradual downward slope to the right. The greater curvature is in front and at a slightly higher level than the lesser.

The position of the full stomach depends, as already indicated, on the state of the intestines: when these are empty the fundus expands vertically and also forwards, the pylorus is displaced towards the right, and the whole organ assumes an oblique position, so that its surfaces are directed more forwards and backwards. The lowest part of the stomach is at the pyloric vestibule, which reaches to the region of

the umbilicus. Where the intestines interfere with the downward expansion of the fundus the stomach retains the horizontal position which is characteristic of the contracted viscus.

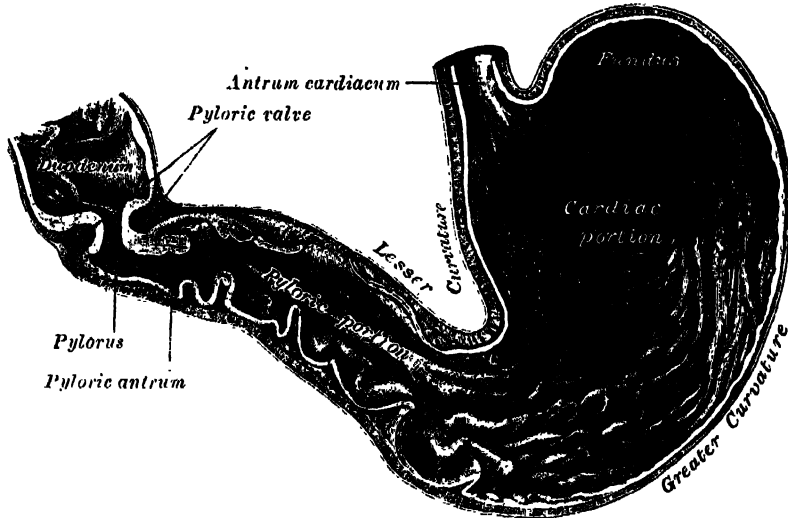
Interior of the stomach.—When examined after death, the stomach is usually fixed

* *Archiv für Anatomie und Physiologie, anat. Abth.*, 1903.

† *Transactions of the Royal Society of Edinburgh*, vol. xlv. part i.

at some temporary stage of the digestive process. A common form is that shown in fig. 1014. If the viscus be laid open by a section through the plane of its two curvatures, it is seen to consist of two segments: (a) a large globular portion on the left and (b) a narrow tubular part on the right. These are separated by a constriction which indents the body and greater curvature, but does not involve the lesser curvature. To the left

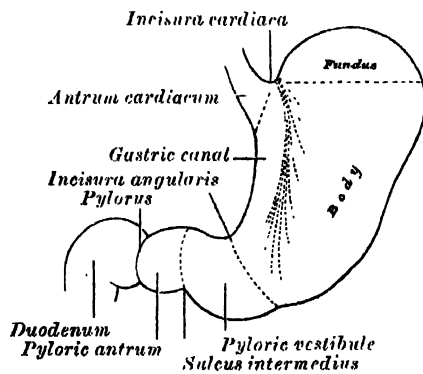
FIG. 1014.—The interior of the stomach.



of the cardiac orifice is the incisura cardiaca: the projection of this notch into the cavity of the stomach increases as the organ distends, and has been supposed to act as a valve preventing regurgitation into the œsophagus. In the pyloric portion are seen: (a) the elevation corresponding to the incisura angularis, and (b) the circular projection from the duodenopyloric constriction which forms the pyloric valve; the separation of the pyloric antrum from the rest of the pyloric part is scarcely indicated.

F. T. Lewis* has modelled the gastric epithelium in the human embryo, and has shown that a canal (named by him the *gastric canal*) extends along the lesser curvature from the antrum cardiacum to the incisura angularis (fig. 1015), the distinctness of the canal being strikingly shown when the model is viewed from the inside. Jefferson† has brought forward radiographic evidence to show that such a canal exists in the adult. He found that in eighteen out of twenty-two cases examined whilst in the act of swallowing a mixture of oxychloride of bismuth and milk the fluid was confined to the lesser curvature. He is of the opinion that the oblique muscular coat of the stomach is so arranged that by its contraction it will cause a temporary cutting off of a canal along the lesser curvature.

FIG. 1015. —Diagram showing the subdivisions of the human stomach. (F. T. Lewis.)



The *pyloric valve* is a muscular ring composed of a thickened portion of the circular layer of the muscular coat; this ring is covered by a reduplication of the mucous membrane. Some of the deeper longitudinal fibres turn in and interlace with the circular fibres of the valve.

Structure.—The wall of the stomach consists of four coats: serous, muscular, areolar, and mucous, together with vessels and nerves.

* The *serous coat* is derived from the peritoneum, and covers the entire surface of the organ, excepting along the greater and lesser curvatures at the lines of attachment of

* *American Journal of Anatomy*, vol. xiii.

† *Journal of Anatomy and Physiology*, vol. xlix.

the greater and lesser omenta; here the two layers of peritoneum leave a small space, triangular in section, along which the nutrient vessels and nerves pass. On the posterior surface of the stomach, close to the cardiac orifice, there is also a small area uncovered by peritoneum, where the organ is in contact with the under surface of the Diaphragm.

FIG. 1016.—The longitudinal and circular muscular fibres of the stomach, viewed from above and in front. (Spalteholz.)

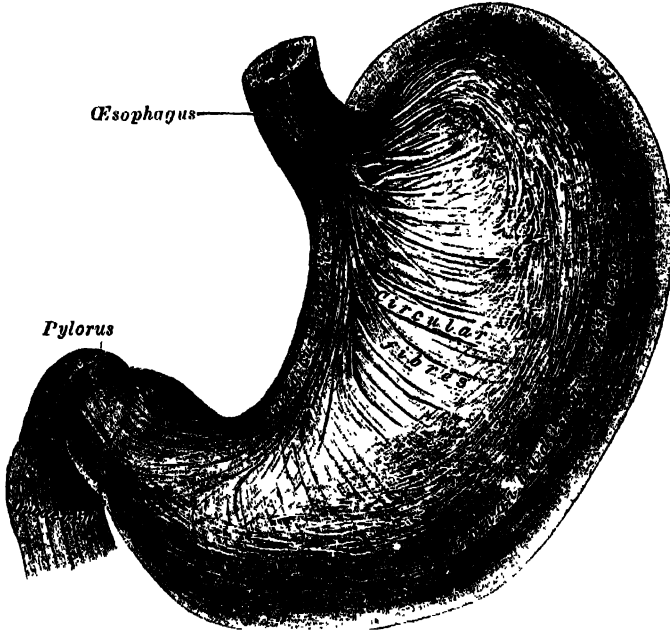
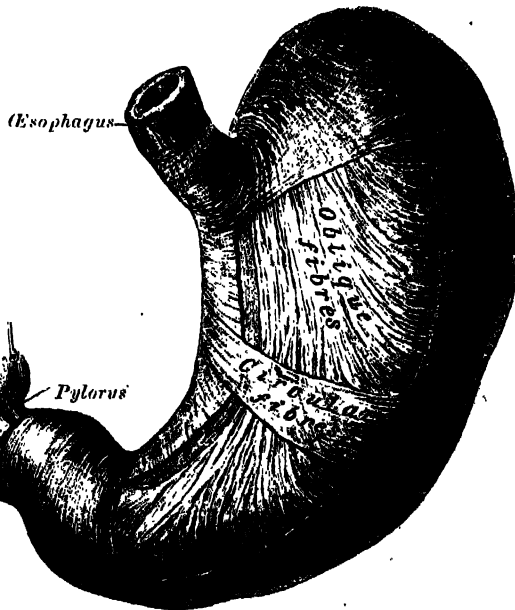


FIG. 1017.—The oblique muscular fibres of the stomach, viewed from above and in front. (Spalteholz.)

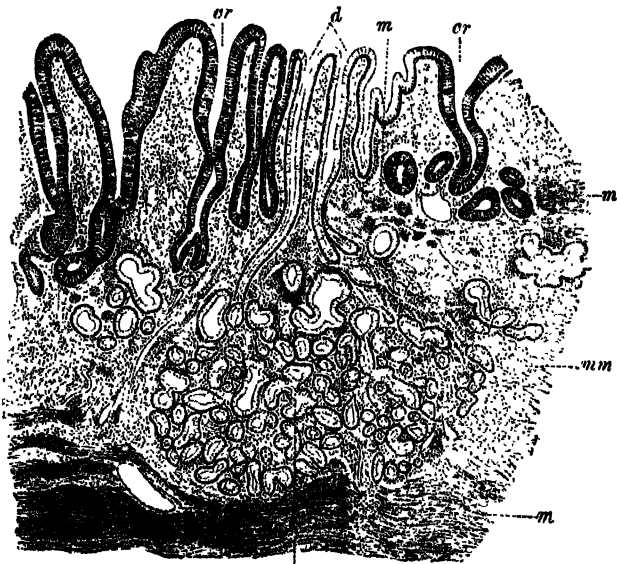


The muscular coat (figs. 1016, 1017) is situated immediately beneath the serous covering, with which it is closely connected. It consists of three layers of unstriped muscular fibres: longitudinal, circular, and oblique.

The *longitudinal fibres* are the most superficial, and are arranged in two sets. The first set consists of fibres continuous with the longitudinal fibres of the œsophagus; they radiate from the cardiac orifice and end proximally to the pyloric portion. The second set commences on the body of the stomach and passes to the right, its fibres becoming more thickly arranged as they approach the pylorus. Some of the more superficial fibres of this set pass on to the duodenum, but the deeper fibres dip inwards and interlace with the circular fibres of the pyloric valve.

The *circular fibres* form a uniform layer over the whole extent of the stomach beneath the longitudinal fibres. At the pylorus they are most abundant, and are aggregated into a circular ring, which forms the *pyloric valve*. They are continuous with the circular fibres of the œsophagus, but are sharply marked off from the circular fibres of the duodenum by a *connective tissue septum*. Owing to the abrupt change in the thickness of the muscular coat at the pyloroduodenal junction, the pyloric wall forms a projection into the lumen of the duodenum.

FIG. 1018.—A section through the mucous membrane of a human stomach, near the cardiac orifice. $\times 45$. (v. Ebner, after J. Schaffer.)



c. Cardiac glands. d. Their ducts. cr. Gland similar to the intestinal glands, with goblet-cells. mm. Mucous membrane. m. Muscularis mucosae. m'. Muscular tissue within the mucous membrane.

The *oblique fibres*, internal to the circular layer, are limited chiefly to the body of the stomach. They sweep downwards from the incisura cardiaca and run more or less parallel with the lesser curvature. On the right they present a free and well-defined margin (fig. 1017); on the left they blend with the circular fibres.

The *areolar or submucous coat* consists of loose, areolar tissue, connecting the mucous and muscular layers.

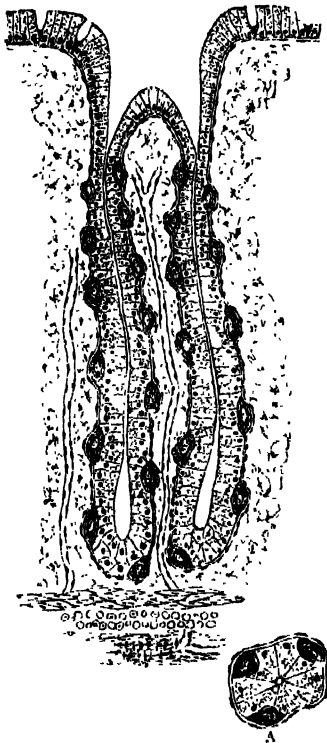
The *mucous membrane* is thick and its surface is smooth, soft, and velvety. In the fresh state it is of a pinkish tinge at the pyloric end, and of a red or reddish-brown colour over the rest of its surface. In infancy it is of a brighter hue, the vascular redness being more marked. It is thin at the cardiac extremity, but thicker towards the pylorus. During the contracted state of the organ it is thrown into numerous folds or *rugae*, which for the most part have a longitudinal direction, and are best marked towards the pyloric end of the stomach, and along the greater curvature (fig. 1014). These folds are obliterated when the organ is distended.

Structure of the mucous membrane.—When examined with a lens, the inner surface of the mucous membrane presents a peculiar honeycomb appearance from being covered with small shallow depressions or *alveoli*, of a polygonal or hexagonal form, which vary from 0.12 mm. to 0.25 mm. in diameter. These are the ducts of the gastric glands, and at the bottom of each may be seen one or more minute orifices, the openings of the gland-tubes. The surface of the mucous membrane is covered by a single layer of columnar epithelium with occasional goblet cells. This epithelium commences very abruptly at the cardiac orifice, where there is a sudden transition from the stratified epithelium of the œsophagus.

The epithelial lining of the gland ducts is of the same character and is continuous with the general epithelial lining of the stomach (fig. 1020).

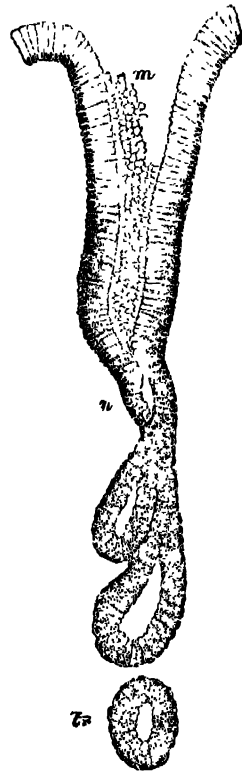
The gastric glands are of three kinds: (a) *cardiac*, (b) *fundus* or *oxyntic*, and (c) *pyloric*. The *cardiac glands* (fig. 1018), few in number, occur close to the cardiac orifice. They are of two kinds: (1) simple tubular glands resembling those of the pyloric end of the stomach, but with short ducts; (2) compound racemose glands resembling the duodenal glands. The *fundus glands* (fig. 1019) are found in the body and fundus of the stomach; they are simple tubes, two or more of which open into a single duct. The duct is short, sometimes not amounting to more than one-sixth of the whole length of the gland. Their epithelium consists of (1) short columnar, granular cells, known as the

FIG. 1019.—A fundus gland.



A. Transverse section of gland.

FIG. 1020.—A pyloric gland, from a section of the dog's stomach. (Ebstein.) (From Quain's Elements of Anatomy, Vol. II. Pt. I.)



m. Mouth. n. Neck. tr. A deep portion of a tubule cut transversely.

chief or central cells, and (2) larger, oval cells, termed *parietal* or *oxyntic* cells. These lie between the chief cells and the basement membrane, and stain deeply with eosin; they do not form a continuous layer but occur at intervals and so give the tube a beaded appearance. They are connected with the lumen of the gland by fine channels which run in the substance of the cells. The *pyloric glands* (fig. 1020) are found in the pyloric portion of the stomach. Each consists of two or three short tubes opening into a funnel-shaped duct. The tubes are convoluted and are about one-half the length of the duct; they are lined by cubical cells which are finely granular. Between the glands the mucous membrane consists of a connective tissue framework, with lymphoid tissue. In places, this latter tissue, especially in early life, is collected into little masses, which resemble the solitary lymphatic nodules of the intestine, and are termed the *lenticular glands* of the stomach. They are not, however, so distinctly circumscribed as the solitary nodules. The mucous membrane is bounded on its deep surface by a thin stratum of involuntary muscular fibre (*muscularis mucosae*), which in some parts consists only of a single longitudinal layer; in others of two layers, an inner circular and an outer longitudinal.

Vessels and Nerves.—The *arteries* supplying the stomach are: the left gastric, the right gastric and right gastro-epiploic branches of the hepatic, and the left gastro-epiploic and short gastric branches of the lienal. They supply the muscular coat, ramify in the submucous coat, and are finally distributed to the mucous membrane. The arrangement of the vessels in the mucous membrane is somewhat peculiar. The arteries break up at the base of the gastric tubules into a plexus of fine capillaries which run upwards between the tubules, anastomosing with each other, and ending in a plexus of larger capillaries, which surround the mouths of the tubes, and also form hexagonal meshes around the ducts. From these the *veins* arise, and pursue a straight course downwards, between the tubules, to the submucous tissue; they end either in the lienal and superior mesenteric veins, or directly in the portal vein. The *lymphatic vessels* are numerous: they consist of a superficial and a deep set, and pass to the lymph-glands found along the two curvatures of the organ (p. 730). The *nerves* are the terminal branches of the right and left vagi, the former being distributed upon the back, and the latter upon the front part of the organ. A great number of branches from the cardiac plexus of the sympathetic are also distributed to it. Nerve-plexuses are found in the submucous coat and between the layers of the muscular coat, as in the intestine. From these plexuses fibrils are distributed to the muscular tissue and the mucous membrane.

Applied Anatomy.—Operations on the stomach are frequently performed. By 'gastrotomy' is meant an incision into the stomach for the removal of a foreign body, the opening being immediately afterwards closed—in contradistinction to 'gastrostomy,' the making of a more or less permanent fistulous opening for purposes of feeding, when the patient cannot obtain sufficient nourishment owing to some form of œsophageal obstruction.

In cases of gastric ulcer perforation of the stomach not infrequently takes place. By opening the abdomen and closing the perforation, the vast majority of cases are cured, provided the operation is done not longer than twelve or fifteen hours after the perforation has taken place. The opening, which is generally situated on the anterior surface of the stomach near the pylorus, is best closed by bringing the peritoneal surfaces on either side into apposition by means of Lembert's sutures. Free drainage of the peritoneal cavity should be established at the same time.

Excision of the pylorus has occasionally been performed, but the results of this operation are by no means favourable, and, in cases of cancer of the pylorus, before operative proceedings are undertaken, the tumour has become so fixed and has so far implicated surrounding parts that removal of the pylorus is impossible and *gastro-enterostomy* has to be substituted. The object of this operation is to make a fistulous communication between the stomach, on the cardiac side of the disease, and the small intestine, as high up as is possible. It gives great relief in any form of obstruction to the pylorus, especially when associated with dilatation of the stomach. In this operation either the anterior or the posterior surface of the stomach may be anastomosed to the jejunum, the latter for preference, in which case an opening has first to be made through the transverse mesocolon in order to reach the lesser sac. This opening must particularly avoid the middle colic vessels. In cases of cancer of the stomach involving other parts than the pylorus, the question of removing the whole or greater part of the stomach has to be considered.

Hypertrophy and spasm of the circumferential muscular coat of the pylorus coming on during the first few weeks or months of life, and somewhat erroneously described as *congenital hypertrophic stenosis of the pylorus*, is a serious disorder of infancy. It is characterised by abdominal pains and obstinate vomiting coming on after food has been given. Gastric peristalsis can be observed by inspection of the child's epigastrium after it has been fed and before vomiting has occurred. Progressive wasting from want of nourishment, and death from exhaustion, tend to ensue. Gastro-enterostomy gives favourable results in a small proportion of cases.

The stomach is seldom ruptured from external violence, on account of its protected position. If it occurs, it is when the organ is distended with food. The stomach is sometimes injured in gunshot wounds. There is intense shock and severe pain, localised at first at the seat of the injury, but soon radiating over the whole abdomen. The treatment consists in opening the peritoneal cavity, clearing away all the extruded contents of the stomach, and repairing the rent.

THE SMALL INTESTINE (INTESTINUM TENUE)

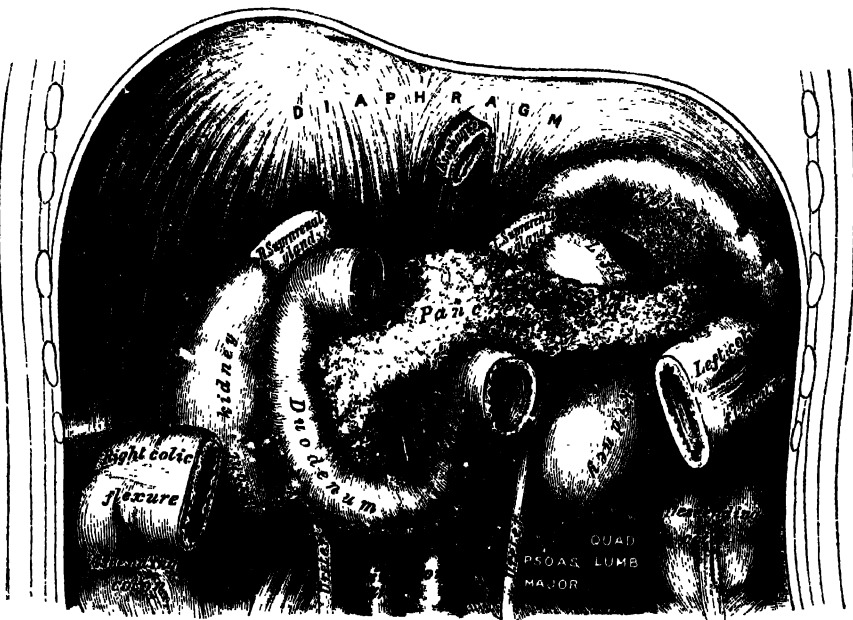
The small intestine is a convoluted tube, extending from the pylorus to the colic valve, where it joins the large intestine. It is about 7 metres long,* and gradually diminishes in diameter from its commencement to its termination.

* Treves states that, in one hundred cases, the average length of the small intestine in the adult male was 22 feet 6 inches, and in the adult female 23 feet 4 inches; but that it varies very much, the extremes in the male being 31 feet 10 inches, and 15 feet 6 inches. He states that in the adult the length of the bowel is independent of age, height, and weight.

It is contained in the central and lower parts of the abdominal cavity and is surrounded above and at the sides by the large intestine; it is in relation, in front, with the greater omentum and abdominal parietes; a portion of it extends below the superior aperture of the pelvis and lies in front of the rectum. The small intestine consists of (1) a short, curved portion which is devoid of a mesentery and is named the duodenum, and (2) a long, greatly coiled part which is attached to the posterior abdominal wall by the mesentery (p. 1095), and is named the *intestinum tenue mesenteriale*; the proximal two-fifths of the latter constitute the jejunum (*intestinum jejunum*), the distal three-fifths the ileum (*intestinum ileum*).

The **duodenum** (fig. 1021) is so named because its length is about equal to the breadth of twelve fingers (25 cm.). It is the shortest, widest, and most fixed part of the small intestine; it has no mesentery, and is only partially

FIG. 1021. — The duodenum and pancreas.



covered by peritoneum. Its course presents a remarkable curve, somewhat of the shape of an imperfect circle, so that its termination is not far removed from its starting-point.

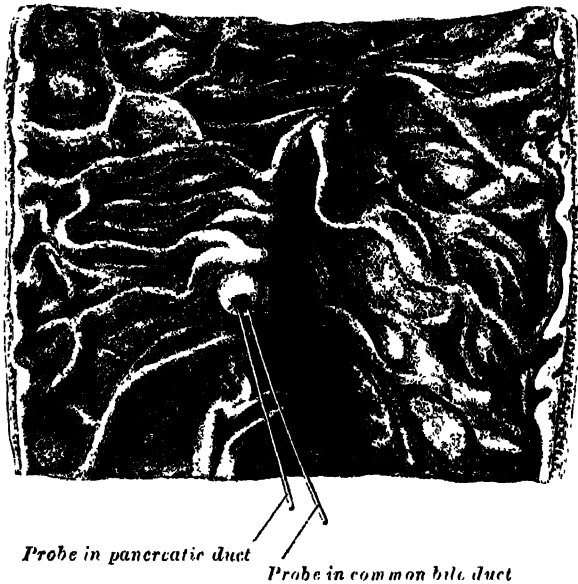
It commences at the pylorus, passes backwards, upwards and to the right, beneath the quadrato lobe of the liver to the neck of the gall-bladder, varying slightly in direction according to the degree of distension of the stomach; it then makes a sharp curve (superior duodenal flexure) and descends along the right margin of the head of the pancreas, for a variable distance, generally to the level of the upper border of the body of the fourth lumbar vertebra. It now makes a second bend (inferior duodenal flexure), and passes almost horizontally from right to left across the vertebral column, having a slight inclination upwards; and on the left side of the vertebral column it ascends for about 2.5 cm., and then ends opposite the second lumbar vertebra in the jejunum. At its union with the jejunum it turns abruptly forwards, forming the *duodenojejunal flexure*. For descriptive purposes it is divided into superior, descending, horizontal, and ascending portions.

Relations.—The *superior portion* is about 5 cm. long, and is the most movable of the four portions; it begins at the pylorus, and ends at the neck of the gall-bladder. It is covered by peritoneum with the exception of a small part of its posterior surface near the neck of the gall-bladder and the inferior

vena cava; the hepatoduodenal ligament is attached to the upper border, and the greater omentum to the lower border of the proximal half. It is in relation above and in front with the quadrato lobe of the liver and the gall-bladder; behind with the gastroduodenal artery, the common bile-duct, and the portal vein; and below and behind with the head and neck of the pancreas. It is in such close relation with the gall-bladder that it is usually found to be stained by bile after death, especially on its anterior surface.

The *descending portion*, from 7 cm. to 10 cm. long, extends from the neck of the gall-bladder, on a level with the first lumbar vertebra, along the right side of the vertebral column as low as the upper border of the body of the fourth lumbar vertebra. It is crossed in its middle third by the transverse colon, the posterior surface of which is here uncovered by peritoneum and

FIG. 1022.—The interior of the descending portion of the duodenum, showing the bile-papilla.



is connected to the duodenum by a small quantity of connective tissue. The parts above and below the transverse colon are covered in front by peritoneum, the part below by the right leaf of the mesentery. Posteriorly, it is not covered by peritoneum. It is in relation, in front, from above downwards, with the duodenal impression on the right lobe of the liver, the transverse colon, and the small intestine; behind, it has a variable relation to the front of the right kidney in the neighbourhood of its hilum, and is connected to it by loose areolar tissue; the renal vessels, the inferior vena cava, and the Psoas below, are also behind it. At its medial side is the head of the pancreas, and the common bile-duct; to its lateral side is the right colic flexure. The common bile-duct and the pancreatic duct together perforate the medial side of this portion of the intestine obliquely (figs. 1022, 1044), from 7 cm. to 10 cm. below the pylorus; the accessory pancreatic duct, when present, pierces it about 2 cm. above and slightly in front of these.

The *horizontal portion*, from 5 cm. to 7.5 cm. long, begins at the right side of the upper border of the fourth lumbar vertebra and passes from right to left, with a slight inclination upwards, in front of the great vessels and the crura of the Diaphragm, and ends in the ascending portion in front of the abdominal aorta. It is crossed from above downwards by the superior mesenteric vessels and the mesentery. Its anterior surface is covered by peritoneum, except near

the middle line, where it is crossed by the superior mesenteric vessels. Its posterior surface is uncovered by peritoneum, except towards its left extremity, where the posterior layer of the mesentery sometimes covers it to a variable extent. This surface rests upon the right crus of the Diaphragm, the inferior vena cava, and the aorta. The upper surface is in relation with the head of the pancreas.

The *ascending portion*, about 2·5 cm. long, ascends on the left side of the aorta, as far as the level of the upper border of the second lumbar vertebra, where it turns abruptly forwards (*duodenojejunal flexure*) and is continuous with the jejunum. It lies in front of the left Psoas major and left renal vessels, and is covered in front, and partly at the sides, by peritoneum continuous with the left portion of the mesentery.

The superior part of the duodenum, as stated above, is somewhat movable, but the rest is practically fixed, and is bound down to neighbouring viscera and the posterior abdominal wall by the peritoneum. In addition to this, the ascending part of the duodenum and the duodenojejunal flexure are fixed by a structure to which the name of *Musculus suspensorius duodeni* has been given. This muscle arises from the right crus of the Diaphragm, close to the right margin of the œsophagus. It passes downwards and slightly forwards in close relation with the celiac artery (sometimes dividing to enclose this vessel) and is attached to the posterior aspect of the upper part of the duodenojejunal flexure, many fibres being continued into the mesentery.* It possesses, according to Treitz, plain muscular fibres mixed with the fibrous tissue of which it is principally made up.

Crymble† confirms the observations of Treitz that this muscle consists of three parts, viz. an upper of striped muscular fibres, an intermediate elastic tendon, and a lower of unstriped muscular fibres.

Vessels and Nerves.—The *arteries* supplying the duodenum are the right gastric and superior pancreaticoduodenal branches of the hepatic, and the inferior pancreaticoduodenal branch of the superior mesenteric. The *veins* end in the liver and superior mesenteric veins. The *nerves* are derived from the celiac plexus.

The **mesenteric part** of the small intestine (*intestinum tenue mesenteriale*), about $6\frac{1}{2}$ metres long, is attached to the posterior abdominal wall by the mesentery, and extends from the duodenojejunal flexure to the colic valve where it ends in the cæcum of the large intestine. It is divided into jejunum and ileum, the former term being given to the upper two-fifths and the latter to the lower three-fifths. There is no morphological line of distinction between the two, and the division is arbitrary; but at the same time the character of the intestine gradually undergoes a change from the commencement of the jejunum to the end of the ileum, so that portions of the bowel taken from these two situations present characteristic and marked differences.

The **jejunum** (*intestinum jejunum*) is wider, its diameter being about 4 cm., and is thicker, more vascular, and of a deeper colour than the ileum. The circular folds or *valvulae conniventes* (p. 1110) of its mucous membrane are large and thickly set, and its villi are larger than in the ileum. The aggregated lymph-nodules are almost absent in the upper part of the jejunum, and in the lower part are less frequently found than in the ileum, and are smaller and tend to assume a circular form. By grasping the jejunum between the finger and thumb the circular folds can be felt through the walls of the gut; these being absent from the lower part of the ileum, it is possible in this way to distinguish the upper from the lower part of the small intestine.

The **ileum** (*intestinum ileum*) is narrower, its diameter being 3·75 cm., and its coats are thinner than those of the jejunum. It possesses few circular folds, and they are small and disappear entirely towards its lower end, but aggregated lymph-nodules (Peyer's patches) are larger and more numerous. The jejunum for the most part occupies the umbilical and left iliac regions, while the ileum lies chiefly in the umbilical, hypogastric, right iliac, and pelvic

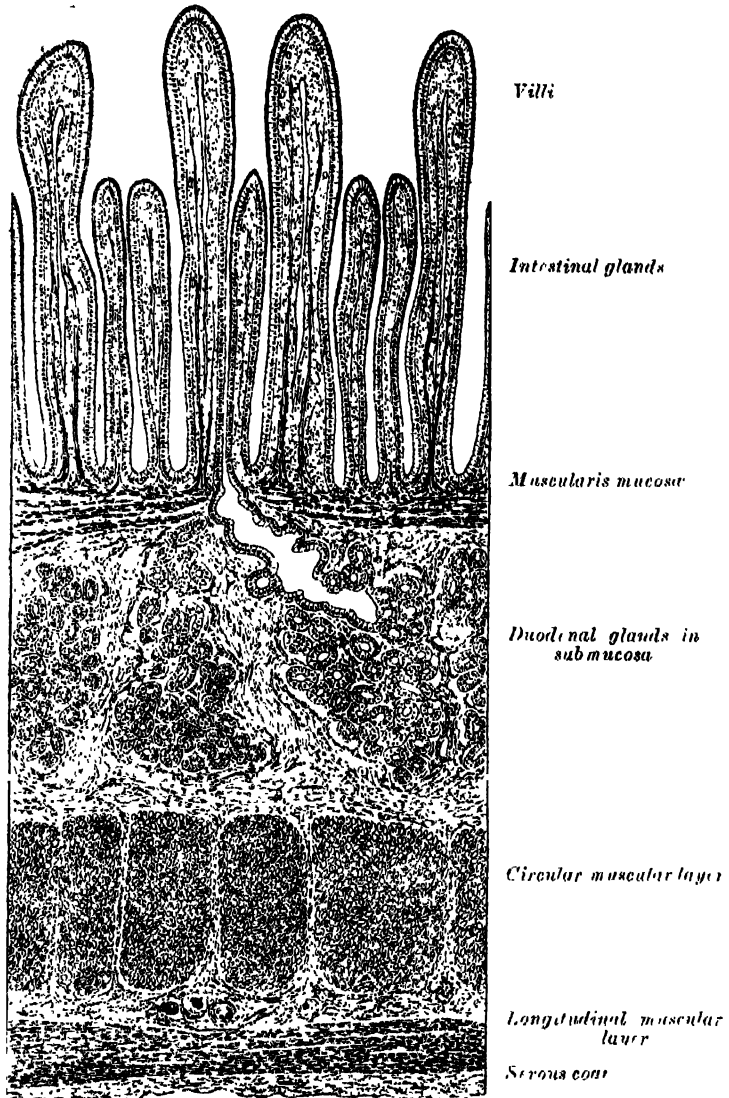
* A. Low (*Journal of Anatomy and Physiology*, vol. xlii.).

† *British Medical Journal*, 1910, vol. ii. p. 1156.

regions. The terminal part of the ileum usually lies in the pelvis, from which it ascends over the right Psoas major and right iliac vessels; it ends in the right iliac fossa by opening into the medial side of the cæcum.

The jejunum and ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, the *mesentery*, which allows of very free motion,

FIG. 1028.—A section of the duodenum of a cat. $\times 60$. (From Schäfer's Essentials of Histology.)



so that each coil can accommodate itself to changes in form and position. The mesentery is fan-shaped; its vertebral border or root, about 15 cm. long, is attached to the posterior abdominal wall along a line running from the left side of the body of the second lumbar vertebra to the right sacro-iliac articulation, and crossing successively the horizontal part of the duodenum, the aorta, the inferior vena cava, the right ureter, and right Psoas major (fig. 1004). Its breadth from the vertebral to the intestinal border averages about 20 cm., and is greater in the middle than at its upper and lower ends; according to Lockwood it tends to increase as age advances. Between the two layers of which the

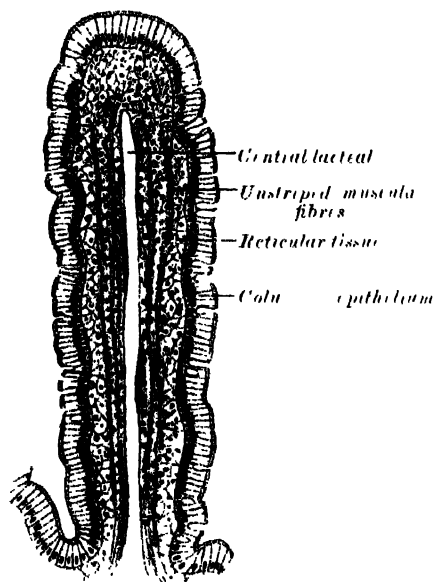
mesentery is composed are contained the jejunum, ileum, the jejunal and ileal branches of the superior mesenteric blood-vessels, nerves, lacteals, and lymph-glands, together with a variable amount of fat.

Meckel's diverticulum.—This is a pouch which projects from the lower part of the ileum in about 2 per cent. of subjects. Its average position is about 1 metre above the colic valve, and its average length about 5 cm. Its calibre is generally similar to that of the ileum, and its blind extremity may be free or may be connected with the abdominal wall or with some other portion of the intestine by a fibrous band. It represents the remains of the proximal part of the vitelline duct, the duct of communication between the yolk-sac and the primitive digestive tube in early fetal life.

Structure.—The wall of the small intestine (fig. 1023) is composed of four coats: serous, muscular, areolar, and mucous.

The *serous coat* is derived from the peritoneum. The superior portion of the duodenum is almost completely surrounded by this membrane near its pyloric end, but is

FIG. 1024.—A vertical section through a villus of the small intestine of a dog. $\times 80$.



only covered in front at the other extremity; the descending portion is covered by it in front, except where it is carried off by the transverse colon; and the inferior portion lies behind the peritoneum, which is separated from it in and near the middle line by the superior mesenteric vessels. The rest of the small intestine is surrounded by the peritoneum, excepting along its attached or mesenteric border; here a space is left for the vessels and nerves to enter the wall of the gut.

The *muscular coat* consists of two layers of unstripped muscular fibres: an external longitudinal, and an internal circular. The *longitudinal layer* is thin: the *circular layer* is thick and is composed of unstripped muscular fibres of considerable length. The muscular coat is thicker at the upper than at the lower part of the small intestine.

The *areolar or submucous coat* unites the mucous and muscular layers. It consists of loose, areolar tissue containing the larger blood-vessels, lymphatics, and nerves.

The *mucous membrane* is thick and highly vascular at the upper part of the small intestine, but somewhat paler and thinner below. It consists of the following structures: next the areolar or submucous coat is the *muscularis mucosa*, a double layer of unstripped muscular fibres, outer longitudinal and inner circular; internal to this is a quantity of retiform tissue, enclosing in its meshes lymph-corpuscles, and in this the blood-vessels and nerves ramify; lastly, a basement membrane, supporting a single layer of tall columnar cells. The cells are granular in appearance, and each possesses a clear oval nucleus. At their superficial or unattached ends they present a distinct layer of highly refracting material, marked by vertical striae (the *striated border*). Goblet cells occur at intervals in the epithelial layer.

Contained within or belonging to the mucous membrane are the following structures:

- ✓ Circular folds.
- ✓ Villi.
- ✓ Intestinal glands.
- ✓ Duodenal glands.
- ✓ Solitary lymphatic nodules.
- ✓ Aggregated lymphatic nodules.

The *circular folds* or *valvulae conniventes* are large valvular flaps projecting into the lumen of the bowel. They are composed of reduplications of the mucous membrane, the two layers of the fold being bound together by submucous tissue; unlike the folds in the stomach, they are permanent, and are not obliterated when the intestine is distended. The majority extend transversely round the intestine for about one-half or two-thirds of its circumference, but some form complete circles, some bifurcate and join adjacent folds, and others have a spiral direction; the latter usually extend a little more than once round the bowel, but occasionally two or three times. The larger folds are about 8 mm. in depth at their broadest part; but the greater number are of smaller size. The larger and smaller folds alternate with each other. Circular folds are not found at the commencement of the duodenum, but begin to appear about 2.5 or 5 cm. beyond the pylorus. In

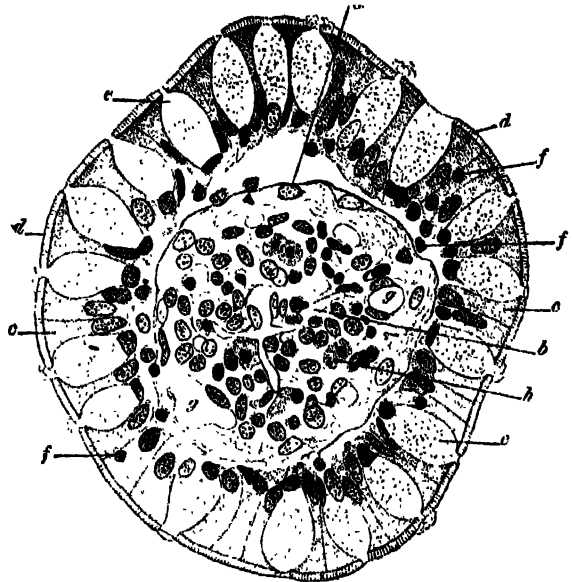
the lower part of the descending portion, below the point where the bile- and pancreatic ducts enter the intestine, they are very large and closely approximated. In the horizontal and ascending portions of the duodenum and upper half of the jejunum they are large and numerous, but from this point, down to the middle of the ileum, they diminish considerably in size. In the lower part of the ileum they almost entirely disappear; hence the comparative thinness of this portion of the intestine, as compared with the duodenum and jejunum. The circular folds retard the passage of the food along the intestine, and afford an increased surface for absorption.

The intestinal villi are highly vascular processes, just visible with the naked eye: they project from the mucous membrane of the small intestine throughout its whole extent, and give to its surface a velvety appearance. They are largest and most numerous in the duodenum and jejunum, and become fewer and smaller in the ileum.

Structure of the villi (figs. 1024, 1025).—The essential parts of a villus are: the lacteal vessel, the blood-vessels, the epithelium, the basement membrane and the muscular tissue of the mucosa, all being supported and held together by retiform lymphoid tissue.

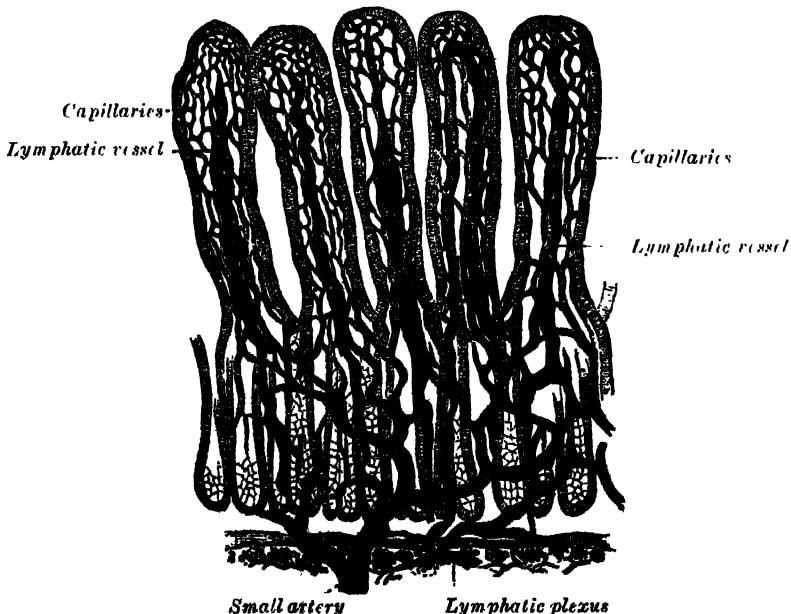
The *lacteals* are in some cases double, and in some animals multiple, but usually there is a single vessel. Situated in the axis of the villus each commences by a dilated blind

FIG. 1025.—A transverse section through a villus of the human intestine. $\times 350$. (v. Ebner.)



a. Basement membrane, here somewhat shrunken away from the epithelium. b. Lacteal. c. Columnar epithelium; d. its striated border. e. Goblet-cells. f. Leucocytes in epithelium. f'. Leucocyte below epithelium. g. Blood-vessels. h. Muscle-cells cut across.

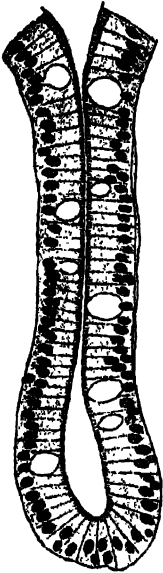
FIG. 1026.—The villi of the small intestine, showing the blood-vessels and the lymphatic vessels. (Cadiat.)



extremity near to, but not quite at, the summit of the villus. The wall is composed of a single layer of endothelial cells.

The *muscular fibres* are derived from the *muscularis mucosæ*, and are arranged in bundles around the lacteal vessel, extending from the base to the summit of the villus, and giving off, laterally, individual muscle-cells, which are enclosed by the reticulum, and by it are attached to the basement membrane and to the lacteal.

FIG. 1027.—An intestinal gland from the human intestine. (Flemming.) (From Quain's Elements of Anatomy, Vol. II. Pt. I.)



The *blood-vessels* (fig. 1026) form a plexus under the basement membrane, and are enclosed in the reticular tissue.

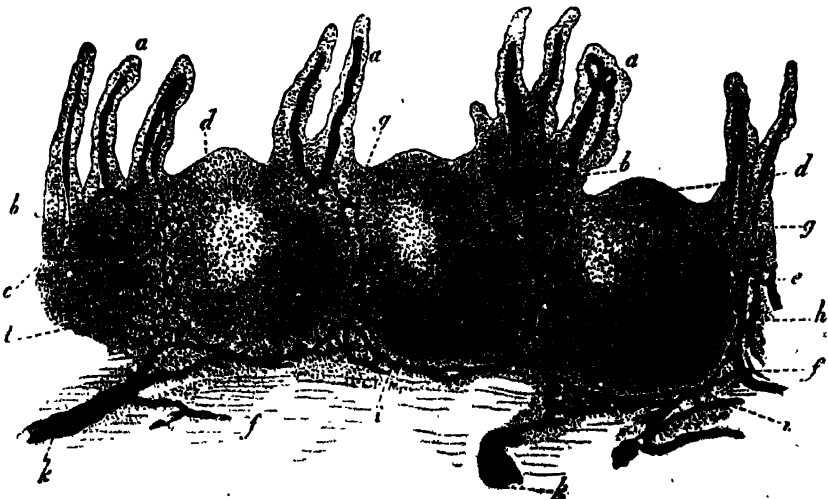
These structures are surrounded by the *basement membrane*, which is made up of a stratum of endothelial cells, and upon this is placed a layer of *columnar epithelium*, the characteristics of which have been described on p. 1110. The *retiform tissue* forms a network (fig. 1025) in the meshes of which a number of leucocytes are found.

The *intestinal glands* (crypts of Lieberkühn) (fig. 1027) are found in considerable numbers over every part of the mucous membrane of the small intestine. They are simple tubular glands, arranged perpendicularly to the surface, upon which they open by small circular apertures. Their orifices may be seen with the aid of a lens as minute dots scattered between the villi. Their walls are thin, consisting of a basement membrane lined by columnar epithelium, and covered on their exterior by capillary vessels.

The *duodenal glands* (Brunner's glands) are limited to the duodenum (fig. 1023), and are found in the submucous areolar tissue. They are largest and most numerous near the pylorus, forming an almost complete layer in the superior portion and upper half of the descending portion of the duodenum. They then begin to diminish in number, and disappear at the junction of the duodenum and jejunum. They are small compound acinotubular glands, each consisting of a number of alveoli lined by short columnar epithelium and opening by a duct on the inner surface of the intestine.

The *solitary lymphatic nodules* are found scattered throughout the mucous membrane of the small intestine, but are most numerous in the lower part of the ileum. Their free surfaces are covered with rudimentary villi, except at the summits, and each nodule is surrounded by the openings of the intestinal glands. Each consists of a dense interlacing retiform tissue closely packed with lymph-corpuscles, and permeated with an abundant capillary network. The interspaces of the retiform tissue are continuous with large lymph-spaces which surround the nodule, through which

FIG. 1028.—A vertical section through a human aggregated lymphatic nodule, injected through the lymphatic vessels.



a. Villi with their lacteals. b. Intestinal glands. c. Muscularis mucosæ. d. Cupula or apex of solitary nodule. e. Mesial zone of nodule. f. Base of nodule. g. Points of exit of the lacteals from the villi, and entrance into the true mucous membrane. h. Retiform arrangement of the lymphatics in the mesial zone. i. Course of the latter at the base of the nodule. j. Confluence of the lymphatics opening into the vessels of the submucous tissue. l. Follicular tissue of the latter

they communicate with the lacteal system. They are situated partly in the submucous tissue, partly in the mucous coat, where they form slight projections of its epithelial layer (fig. 1028).

The **aggregated lymphatic nodules** (Peyer's glands) (fig. 1028) form circular or oval patches, from twenty to thirty in number, and vary in length from 2 cm. to 10 cm.

FIG. 1029.—A transverse section through the equatorial plane of three lymphatic nodules of the rabbit.

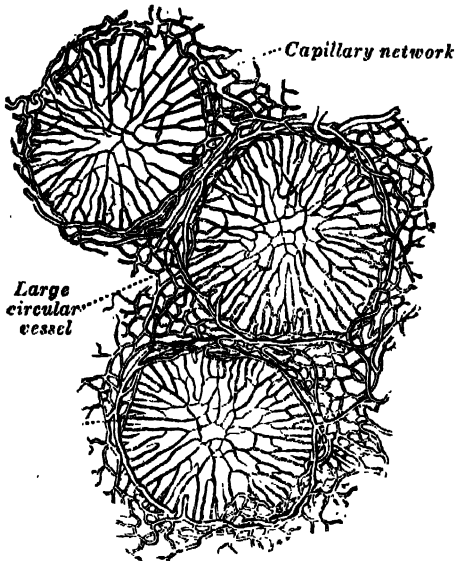
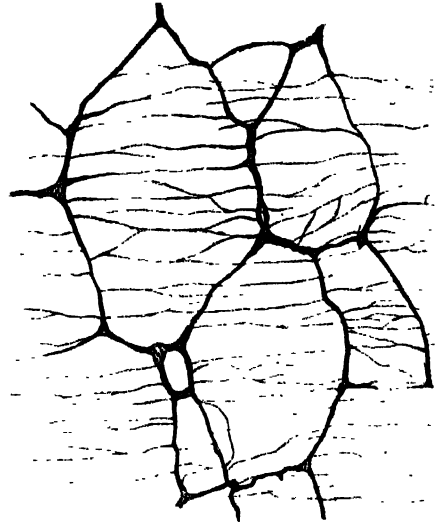


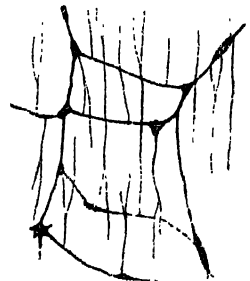
FIG. 1030.—The myenteric plexus of the rabbit. $\times 50$.



They are largest and most numerous in the ileum. In the lower part of the jejunum they are small, circular, and few in number. They are occasionally seen in the duodenum. They are placed lengthwise in the intestine, and are situated in the portion of the tube most distant from the attachment of the mesentery. Each patch is formed of a group of solitary lymphatic nodules covered with columnar epithelium; the patches do not, as a rule, possess villi on their free surfaces. They are best marked in the young subject, become indistinct in middle age, and sometimes disappear altogether in advanced life. They are freely supplied with blood-vessels (fig. 1029), which form an abundant plexus around each follicle and give off fine branches permeating the lymphoid tissue in the interior of the follicle. The lymphatic plexuses are especially abundant around these patches.

Vessels and Nerves.—The jejunum and ileum are supplied by the superior mesenteric artery, the jejunal and ileal branches of which, having reached the attached border of the bowel, run between the serous and muscular coats, with frequent anastomoses, to the free border, where they also anastomose with other branches running round the opposite surface of the gut. From these vessels numerous branches are given off, which pierce the muscular coat, supplying it and forming an intricate plexus in the submucous tissue. From this plexus minute vessels pass to the glands and villi of the mucous membrane. The veins have a course and arrangement similar to the arteries. The lymphatics of the small intestine (lacteals) are arranged in two sets, those of the mucous membrane and those of the muscular coat. The lymphatics of the villi commence in these structures in the manner described above. They form an intricate plexus in the mucous and submucous tissue, being joined by the lymphatics from the lymph-spaces at the bases of the solitary nodules, and from this pass to larger vessels at the mesenteric border of the gut. The lymphatics of the muscular coat are situated to a great extent between the two layers of muscular fibres, where they form a close plexus; throughout their course they communicate freely with the lymphatics from the mucous membrane, and empty themselves in the same manner as these into the origins of the lacteal vessels at the attached border of the gut.

FIG. 1031.—The plexus of the submucosa of the rabbit. $\times 50$.



The *nerves* of the small intestine are derived from the plexuses of *sympathetic* nerves around the superior mesenteric artery. From this source they run to the *myenteric plexus* (*Auerbach's plexus*) (fig. 1030) of nerves and ganglia, situated between the circular and longitudinal layers, from which the nervous branches are distributed to the muscular coats of the intestine. From the myenteric plexus a secondary plexus, the *plexus of the submucosa* (*Meissner's plexus*) (fig. 1031), is derived, and is formed by branches which have perforated the circular muscular layer. This plexus lies in the submucous coat of the intestine; it also contains ganglia from which the nerve-fibres pass to the muscularis mucosae and to the mucous membrane. The nerve-bundles of the submucous plexus are finer than those of the myenteric plexus.

Keith states that 'Auerbach's plexus is not composed simply of ganglionic cells and nerve-fibres; it contains numerous other cells to which Kölliker called attention, and which may be described as Kölliker's cells. These cells have small bodies which send out numerous branched processes, and differ from pure sheath cells in staining reaction and structure. It is through these cells that Auerbach's tissue is linked up with the musculature of the bowel. The nerve-fibres which former authors have described as distributed to the muscular and other coats of the bowel are probably sensory in nature. Sections of the developing bowel show that the outer and inner muscular coats are developed from a germinal layer situated between them. Auerbach's plexus represents the residue of the germinal or developmental intermediate layer. Probably the ganglionic cells may be of central origin, but the cells of Kölliker are apparently undifferentiated muscle-cells.' He states that in point of development Auerbach's plexus is similar in origin to that of the atrioventricular bundle of His, and is of opinion that they are homologous.*

THE LARGE INTESTINE (INTESTINUM CRASSUM)

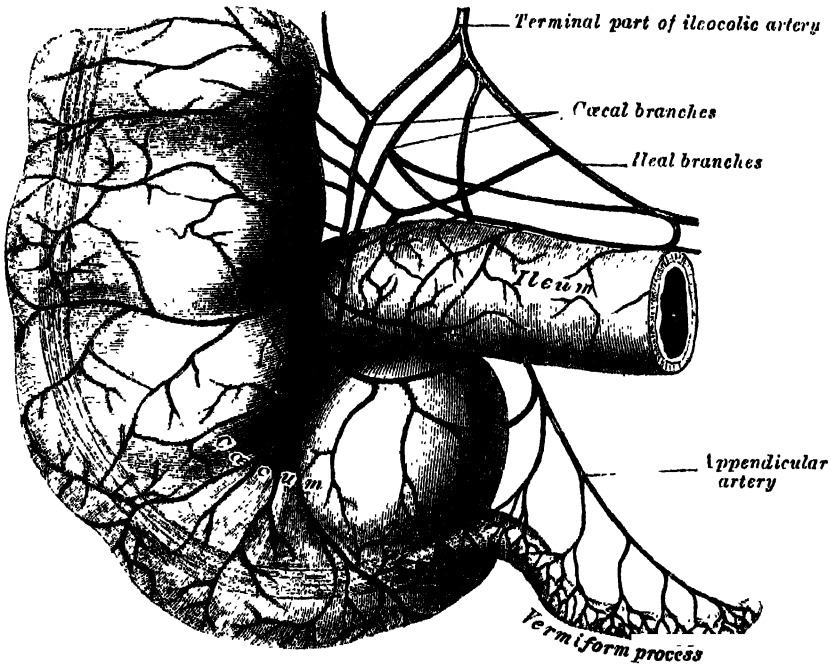
The *large intestine* extends from the end of the ileum to the anus. It is about 1·5 metres long, being one-sixth of the whole extent of the intestinal canal. Its calibre is largest at its commencement at the cæcum, and gradually diminishes as far as the rectum, where there is a dilatation of considerable size just above the anal canal. It differs from the small intestine in its greater calibre, its more fixed position, its sacculated form, and in possessing certain appendages to its external coat, the *appendices epiploicae*. Further, its longitudinal muscular fibres do not form a continuous layer around the gut, but are arranged in three longitudinal bands or *taeniae*. In its course the large intestine describes an arch which surrounds the convolutions of the small intestine. It commences in the right iliac region, in a dilated part, the *cæcum*. It ascends through the right lumbar and hypochondriac regions to the under surface of the liver; here it bends (the *right colic flexure*) to the left, and passes transversely across the abdomen on the confines of the epigastric and umbilical regions, to the left hypochondriac region; it then bends again (the *left colic flexure*), and descends through the left lumbar and iliac regions to the pelvis, where it forms a loop called the *sigmoid flexure*; from this it is continued along the lower part of the posterior wall of the pelvis to the anus. It is divided into the cæcum, the colon, the rectum, and the anal canal.

The *cæcum* (fig. 1032), the commencement of the large intestine, is the large pouch situated below the colic valve. Its closed end is directed downwards, and its open end upwards, communicating directly with the colon, of which the cæcum appears to be the beginning or head, and hence the name *caput cæcum coli* was formerly applied to it. Its size is variously estimated by different authors, but on an average it may be said to be 6·25 cm. in length and 7·5 cm. in breadth. It is situated in the right iliac fossa, above the lateral half of the inguinal ligament: it rests on the Iliacus and Psoas major, and is usually in contact with the anterior abdominal wall, but the greater omentum, and, if the cæcum be empty, some coils of small intestine, may lie in front of it. As a rule, it is entirely enveloped by peritoneum, but in about 5 per cent. of cases (Berry) the peritoneal covering is not complete, so that the upper part of the posterior surface is uncovered and is connected to the iliac fascia by connective tissue. The cæcum enjoys a considerable amount of movement, so that it may become herniated down the right inguinal canal, and has occasionally been found in an inguinal hernia on the left side. The cæcum varies in shape, but, according to Treves, it may be classified under one of four types. In early foetal life it is short, conical, and broad at the base, with its apex

* *Proceedings of the Anatomical Society of Great Britain and Ireland, January 1915.*

turned upwards and medialwards towards the ileocolic junction. It then resembles the cæcum of some monkeys, e.g. the mangabey monkey. As the foetus grows, the cæcum increases in length more than in breadth, so that it forms a longer tube than in the primitive form and without the broad base, but with the same inclination of the apex towards the ileocolic junction. This form is seen in other monkeys, e.g. the spider monkey. As development goes on, the lower part of the tube ceases to grow and the upper part becomes greatly increased, so that at birth there is a narrow tube, the vermiform process, hanging from a conical projection, the cæcum. This is the infantile form, and as it persists throughout life in about 2 per cent. of cases, it is regarded by Treves as the *first* of his four types of human cæca. The cæcum is conical and the appendix rises from its apex. The three longitudinal bands start from the appendix and are equidistant from each other. In the *second* type, the

FIG. 1032.—The cæcum and vermiform process, with their arteries.



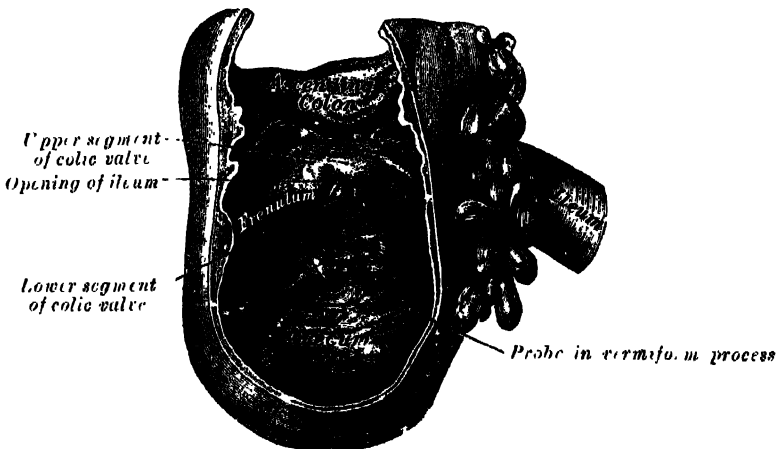
conical cæcum has become quadrate by the growing out of a saccule on either side of the anterior longitudinal band. These saccules are of equal size, and the appendix arises from between them, instead of from the apex of a cone. This type is found in about 3 per cent. of cases. The *third* type is the normal type of man. Here the two saccules, which in the second type were uniform, have grown at unequal rates: the right with greater rapidity than the left. In consequence of this an apparently new apex has been formed by the growing downwards of the right saccule, and the original apex, with the appendix attached, is pushed over to the left towards the ileocolic junction. The three longitudinal bands still start from the base of the vermiform process, but they are now no longer equidistant from each other, because the right saccule has grown between the anterior and posterolateral bands, pushing them over to the left. This type occurs in about 90 per cent. of cases. The *fourth* type is merely an exaggerated condition of the third; the right saccule is still larger, and at the same time the left saccule has become atrophied, so that the original apex of the cæcum, with the vermiform process, is close to the ileocolic junction, and the anterior band courses medialwards to the same situation. This type is present in about 4 per cent. of cases.

The colic valve (fig. 1033).—The lower part of the ileum ends by opening into the medial and posterior part of the large intestine, at the point of junction

of the cæcum with the colon. The opening is guarded by a valve, consisting of two segments or lips, which project into the lumen of the large intestine. If the intestine has been inflated and dried, the lips are of a semilunar shape. The upper lip, nearly horizontal in direction, is attached by its convex border to the line of junction of the ileum with the colon; the lower one, which is longer and more concave, is attached to the line of junction of the ileum with the cæcum. At the ends of the aperture the two segments of the valve coalesce, and are continued as narrow membranous ridges around the canal for a short distance, forming the *frenula* of the valve. The left or anterior end of the aperture is rounded; the right or posterior is narrow and pointed. In the fresh condition, or in specimens which have been hardened *in situ*, the lips project as thick cushion-like folds into the lumen of the large gut, while the opening between them may present the appearance of a slit or may be somewhat oval in shape.

Each lip of the valve is formed by a reduplication of the mucous membrane and of the circular muscular fibres of the intestine, the longitudinal fibres

FIG. 1033.--The interior of the cæcum and the lower end of the ascending colon, showing the colic valve.



and peritoneum being continued uninterruptedly from the small to the large intestine.

The surfaces of the valve directed towards the ileum are covered with villi and present the characteristic structure of the mucous membrane of the small intestine; while those turned towards the large intestine are destitute of villi, and marked with the orifices of the numerous tubular glands peculiar to the mucous membrane of the large intestine. It is generally maintained that this valve prevents reflux from the cæcum into the ileum, but in all probability it acts as a sphincter round the end of the ileum and prevents the contents of the ileum from passing too quickly into the cæcum.

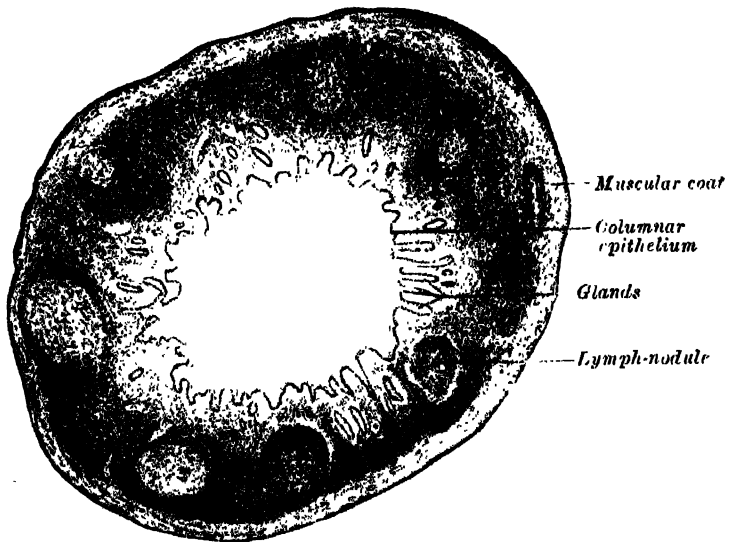
The **vermiform process** or **appendix** (fig. 1032) is a long, narrow, worm-shaped tube, which starts from what was originally the apex of the cæcum, and may pass in one of several directions: upwards behind the cæcum; to the left behind the ileum and mesentery; or downwards into the lesser pelvis. It varies from 2 cm. to 20 cm. in length, the average being about 9 cm. It is retained in position by a fold of peritoneum (mesenteriole), derived from the mesentery. This fold, in the majority of cases, is more or less triangular in shape, and as a rule extends along the entire length of the tube. Between its two layers and close to its free margin lies the appendicular artery (fig. 1032). The canal of the vermiform process is small, extends throughout the whole length of the tube, and communicates with the cæcum by an orifice which is placed below and behind the ileocaecal opening. The orifice is sometimes

guarded by a semilunar valve formed by a fold of mucous membrane, but this is by no means constant.

Structure.—The coats of the vermiform process are the same as those of the intestine: serous, muscular, submucous, and mucous. The *serous* coat forms a complete investment for the tube, except along the narrow line of attachment of its mesenteriole in its proximal two-thirds. The *longitudinal muscular fibres* do not form three bands as in the greater part of the large intestine, but invest the whole organ, except at one or two points where both the longitudinal and circular layers are deficient, so that the peritoneal and submucous coats are contiguous over small areas. The *circular muscular fibres* form a thicker layer than the longitudinal fibres, and are separated from them by a small amount of connective tissue. The *submucous* coat is well marked, and contains a large number of masses of lymphoid tissue which cause the mucous membrane to bulge into the lumen and so render the latter of small size and irregular shape. The *mucous membrane* is lined by columnar epithelium and resembles that of the rest of the large intestine, but the intestinal glands are fewer in number (fig. 1034).

The colon is divided into four parts: the ascending, transverse, descending, and sigmoid.

FIG. 1034.—Transverse section of human vermiform process. $\times 20$.

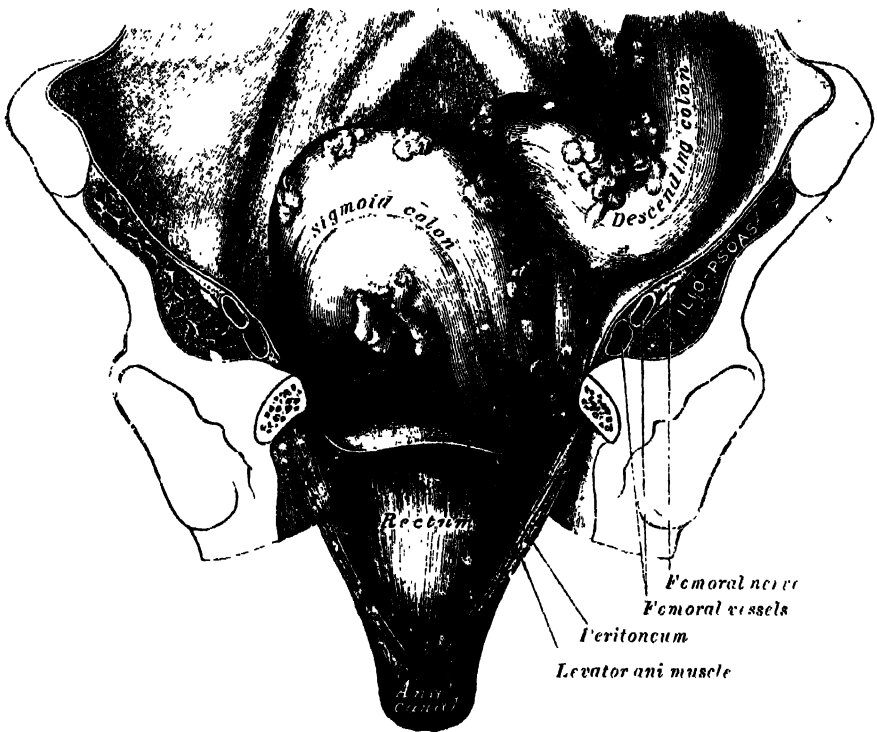


The **ascending colon**, about 15 cm. long, is smaller in calibre than the cæcum. It begins at the cæcum, and ascends to the under surface of the right lobe of the liver, where it is lodged in a shallow depression, the colic impression; here it bends abruptly forwards and to the left, forming the *right colic (hepatic) flexure* (fig. 1021). It is retained in contact with the posterior wall of the abdomen by the peritoneum, which covers its anterior surface and sides, its posterior surface being connected by loose areolar tissue with the Iliacus, Quadratus lumborum, aponeurotic origin of Transversus abdominis, and with the front of the lower and lateral part of the right kidney. Sometimes the peritoneum completely invests it, and forms a distinct but narrow mesocolon.* It is in relation, in front, with the convolutions of the ileum and the abdominal parietes.

* Traves, after a careful examination of one hundred subjects, found that in fifty-two there was neither an ascending nor a descending mesocolon. In twenty-two there was a descending mesocolon, but no trace of a corresponding fold on the other side. In fourteen subjects there was a mesocolon to both the ascending and the descending segments of the bowel; while in the remaining twelve there was an ascending mesocolon, but no corresponding fold on the left side. It follows, therefore, that in performing lumbar colotomy a mesocolon may be expected upon the left side in 36 per cent. of all cases, and on the right in 26 per cent.—*The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885, p. 55.

The **transverse colon**, about 50 cm. long, passes with a downward convexity from the right hypochondriac region across the abdomen, opposite the confines of the epigastric and umbilical zones, into the left hypochondriac region, where it curves sharply backwards on itself beneath the lower end of the spleen, forming the *left colic (splenic) flexure*. In its course it describes an arch, the concavity of which is usually directed backwards and a little upwards; towards its splenic end there is often an abrupt U-shaped curve which may descend lower than the main curve. It is almost completely invested by peritoneum, and is connected to the anterior border of the pancreas by the *transverse mesocolon*. It is in relation, by its upper surface, with the liver and gall-bladder, the greater curvature of the stomach, and the lower end

FIG. 1035.—The descending colon, sigmoid colon, and rectum, seen from the front, after the removal of the pubic bones and bladder.



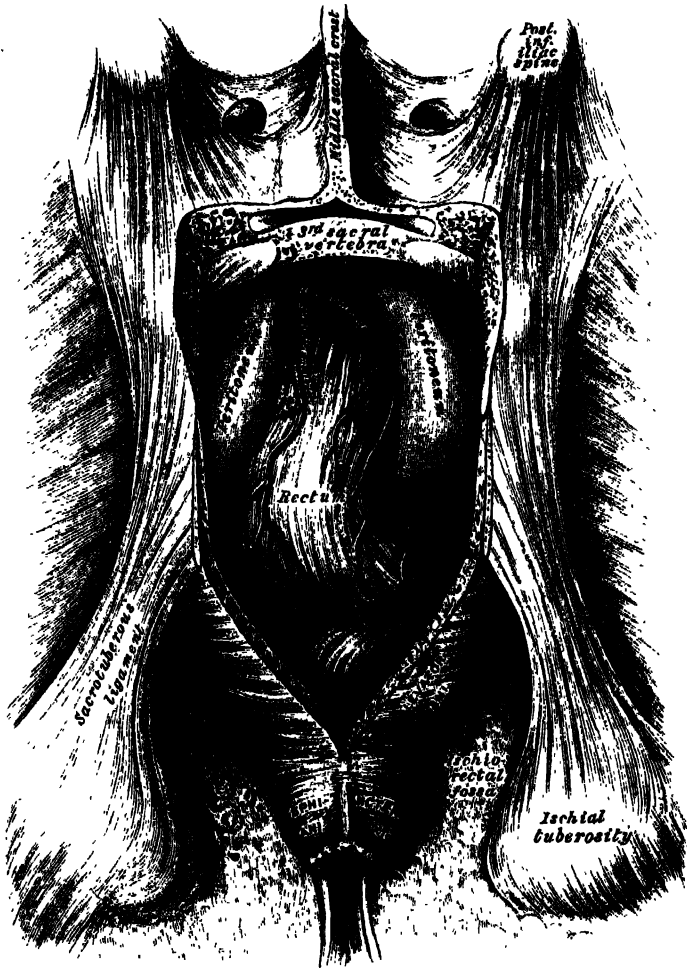
of the spleen; by its under surface, with the small intestine; by its anterior surface with the anterior layers of the greater omentum and the abdominal parietes; its posterior surface is in relation from right to left with the descending portion of the duodenum, the head of the pancreas, and some of the convolutions of the jejunum and ileum.

The *left colic or splenic flexure* (fig. 1021) is situated at the junction of the transverse and descending parts of the colon, and is in relation with the lower end of the spleen and the tail of the pancreas; the flexure is so acute that the end of the transverse colon usually lies in contact with the front of the descending colon. The left colic flexure lies at a higher level than, and on a plane posterior to, the right, and is attached to the Diaphragm, opposite the tenth and eleventh ribs, by a peritoneal fold, named the *phrenicocolic ligament*, which assists in supporting the lower end of the spleen (p. 1096).

The **descending colon** passes downwards through the left hypochondriac and lumbar regions and in front of the lower part of the left kidney. At the lower end of the kidney it turns medialwards towards the lateral border of the Psoas major, and descends, in the angle between Psoas major and Quadratus lumborum,

to the crest of the ilium ; it then curves downwards and medialwards in front of the Iliacus and Psoas major, and ends in the sigmoid colon at the superior aperture of the lesser pelvis.* The peritoneum covers its anterior surface and sides, while its posterior surface is connected by areolar tissue with the lower and lateral part of the left kidney, the aponeurotic origin of the Transversus abdominis, the Quadratus lumborum, the Iliacus and the

FIG. 1036.—The posterior aspect of the rectum exposed by removing the lower part of the sacrum and the coccyx.



Psoas major (figs. 1021 and 1035). It is smaller in calibre, more deeply placed, and more frequently covered with peritoneum on its posterior surface, than the ascending colon (Treves). In front of it are some coils of small intestine.

The sigmoid colon (sometimes called the *pelvic colon*) (fig. 1035) forms a loop which averages about 20 cm. in length, and normally lies within the pelvis. It begins at the superior aperture of the lesser pelvis, where it is continuous with the descending colon, and the loop consists of three parts: the first descends in contact with the left pelvic wall; the second crosses the pelvic cavity, between the rectum and bladder in the male, and the rectum and uterus

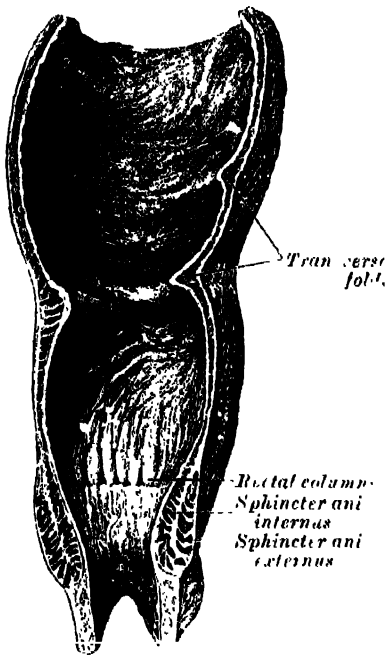
*That portion of the descending colon which extends from the crest of the ilium to the superior aperture of the lesser pelvis is sometimes named the *Siac colon*.

in the female, and may come into contact with the right pelvic wall; the third arches backwards and reaches the middle line at the level of the third piece of the sacrum, where it bends downwards and ends in the rectum. The sigmoid colon is completely surrounded by peritoneum, which forms a mesentery, the *sigmoid mesocolon* (p. 1096); this diminishes in length from the centre towards the ends of the loop, where it disappears, so that the loop is fixed at its junctions with the descending colon and rectum, but enjoys a considerable range of movement in its central portion. Behind the sigmoid colon are the external iliac vessels, the left Piriformis, and left sacral plexus of nerves; in front of it are some coils of the small intestine which separate it from the bladder in the male, and from the uterus in the female.

The position and shape of the sigmoid colon vary very much, and depend on (a) its length; (b) the length and freedom of its mesocolon; (c) the condition of distension; when distended it rises out of the pelvis into the abdominal cavity, and when empty it sinks again into the pelvis; (d) the condition of the rectum and bladder (and the uterus, in the female); when these organs are distended the sigmoid colon tends to rise, and conversely.

The **rectum** (figs. 1035, 1036) is continuous above with the sigmoid colon, whilst below it ends in the anal canal. From its origin at the level of the third sacral vertebra it passes downwards, lying in the sacrococcygeal curve, and extends for about 2.5 cm. in front of, and a little below, the tip of the coccyx, as far as the apex of the prostate. It then bends sharply backwards into the anal canal. It therefore presents two anteroposterior flexures: an upper or *sacral flexure* with its convexity backwards, and a lower or *perineal flexure*, with its convexity forwards. Two lateral curves are also described, one convex to the right opposite the junction of the third and fourth sacral vertebrae, and the other to the left, opposite the sacrococcygeal articulation; they are, however, of little importance. The rectum is about 12 cm. long, and at its commencement its calibre is similar to that of the sigmoid colon, but near its termination it is dilated to form the *rectal ampulla*. It has no sacculations comparable to those of the colon, but when the lower part of it is contracted its mucous membrane is thrown into a number of folds, which are longitudinal in direction and are effaced by the distension of the gut. Besides these there are certain permanent *transverse folds* (plicæ transversales recti), of a semilunar shape, known as *Houston's*

FIG. 1037.—A coronal section of the rectum and anal canal.



valves (fig. 1037). There are usually three, but sometimes a fourth or fifth is found, and occasionally only two are present. One is situated near the commencement of the rectum, on the right side; a second extends inwards from the left side of the tube, opposite the middle of the sacrum; a third, the largest and most constant, projects backwards from the fore part of the rectum, opposite the fundus of the urinary bladder. When a fourth is present, it is situated nearly 2.5 cm. above the anus on the left and posterior wall of the tube. These folds are about 12 mm. in width and contain some of the circular fibres of the gut. In the empty state of the intestines they overlap each other, as Houston remarks, so effectually as to require considerable manœuvring to conduct a bougie or the finger along the canal. Their use seems to be to support the weight of faecal matter, and prevent its urging

wards the anus, where its presence always excites a sensation demanding discharge.*

The peritoneum is related to the upper two-thirds of the rectum, covering at first its front and sides, but lower down its front only; from the latter it is reflected on to the seminal vesicles in the male and the posterior vaginal wall in the female.

The level at which the peritoneum is reflected from the rectum on to the viscus in front of it is higher in the male than in the female. In the former the height of the rectovesical excavation is about 7.5 c.m. (i.e. the height to which an ordinary index finger can reach) from the anus. In the female the height of the recto-uterine excavation is about 5.5 cm. from the anal orifice. The rectum is surrounded by a dense tube of fascia derived from the fascia endopelvina, but fused behind with the fascia covering the sacrum and coccyx. The fascial tube is loosely attached to the rectal wall by areolar tissue, in order to allow of distension of the viscus.

Relations of the rectum.—

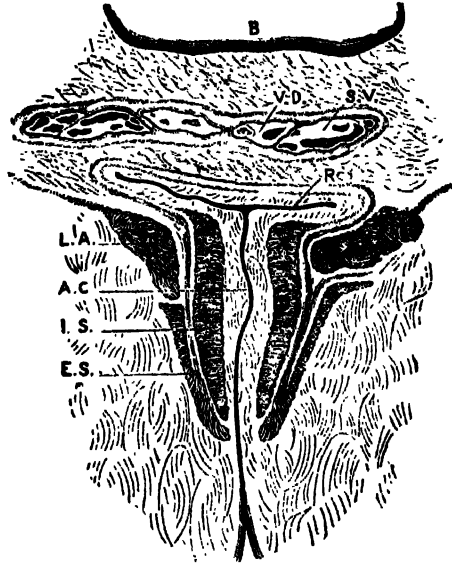
The upper part of the rectum is in relation, *behind*, with the superior hæmorrhoidal vessels, the left Piri-formis and the left sacral plexus of nerves, which separate it from the pelvic surfaces of the sacral vertebræ; its lower part lies on the sacrum, coccyx, and Levatores ani; it is attached to the sacrum along the lines of the sacral foramina by connective tissue which surrounds the sacral nerves and branches of the superior hæmorrhoidal vessels passing to the bowel. *In front* of its upper part, in the male, is the rectovesical excavation;

in the female, the recto-uterine excavation of the peritoneum. In either sex the excavation contains some convolutions of the small intestine, and frequently the sigmoid colon. Below the rectovesical excavation, its anterior surface is in relation in the male with the triangular portion of the fundus of the bladder, the vesiculæ seminales, and ductus deferentes, and more anteriorly with the posterior surface of the prostate; in the female, with the posterior wall of the vagina.

The anal canal (*pars analis recti*) (fig. 1038) begins at the level of the apex of the prostate, is directed downwards and backwards, and ends at the anus. It forms an angle with the lower part of the rectum, and measures about 2.5 cm. in length. It has no peritoneal covering, but is invested by the Sphincter ani internus, supported by the Levatores ani, and surrounded at its termination by the Sphincter ani externus. In the empty condition it presents the appearance of an anteroposterior longitudinal slit. Behind it, is a mass of muscular and fibrous tissue, the *anococcygeal body* (Symington); in front of it, in the male, but separated from it by connective tissue, are the membranous portion and bulb of the urethra, and the fascia of the urogenital diaphragm; and in the female it is separated from the lower end of the vagina by a mass of muscular and fibrous tissue, named the *perineal body*.

* Paterson (The Form of the Rectum, *Journal of Anatomy and Physiology*, vol. xlii.) utilises the third fold for the purpose of dividing the rectum into an upper and a lower portion; he considers the latter 'to be just as much a duct as the narrower anal canal below,' and maintains that, under normal conditions, it does not contain faeces except during the act of defecation.

FIG. 1038.—A coronal section through the anal canal. (Symington.)



A.C. Anal canal. B. Cavity of urinary bladder. E.S. Sphincter ani externus. I.S. Sphincter ani internus. L.A. Levator ani. R. Second part of rectum. S.V. Seminal vesicle. V.D. Ductus deferens.

The upper half of the anal canal is lined by mucous membrane which presents from six to ten vertical folds known as the *rectal columns* (*Morgagni*) (fig. 1037). They are produced by an infolding of the mucous membrane and some of the longitudinal muscular tissue, and are separated from one another by furrows which end below in small crescentic valve-like folds, termed *anal valves*; these valves join together the lower ends of the rectal columns, and outside each valve is a small pouch or *rectal sinus*.

The lower half of the anal canal is lined by skin which exhibits a series of folds extending upwards from the anus towards the rectal columns. The junction of the skin and mucous membrane is indicated by a white line which is somewhat wavy owing to the interlocking of the cutaneous and mucous folds' (Symington).

The **anus** or **anal orifice** is the lower aperture of the anal canal, and is situated in front of the apex of the coccyx in the cleft between the buttocks. The skin surrounding it is thrown into a series of folds which converge towards the orifice and are continued upwards into the lower part of the anal canal.

Structure of the colon--The large intestine has four coats: serous, muscular, areolar, and mucous.

The *serous coat* is derived from the peritoneum, and invests the different portions of the large intestine to a variable extent. The cæcum is usually completely covered by the serous membrane, but in about 5 per cent. of cases the upper part of the posterior surface is uncovered. The ascending and descending parts of the colon are usually covered only in front and at the sides: a variable amount of the posterior surface is uncovered.* The transverse colon is invested with the exception of (a) the posterior surface of that part which lies in front of the duodenum and the head of the pancreas, and (b) along the lines of attachment of the greater omentum and transverse mesocolon. The sigmoid colon is entirely surrounded. The upper part of the rectum is covered on its anterior surface and sides; the middle part on its anterior surface only; while the lower 5 cm. of the rectum and the anal canal are devoid of any serous covering. In the course of the colon the peritoneal coat is thrown into a number of small pouches filled with fat, called *appendices epiploicae*. They are most numerous on the transverse colon.

The *muscular coat* consists of an external longitudinal, and an internal circular layer of non-striped muscular fibres.

The *longitudinal fibres* do not form a continuous layer over the whole surface of the large intestine. In the cæcum and colon they are especially collected into three flat longitudinal bands (*tæniæ coli*), each of about 12 mm. in width; one, the posterior (*tænia mesocolica*), is placed along the attached border of the intestine; the anterior, the largest (*tænia omentalis*), corresponds, along the arch of the colon, with the attachment of the greater omentum, but is in front in the ascending, descending, and sigmoid parts of the colon; the third (*tænia libera*) is found on the medial side of the ascending and descending parts of the colon, and on the under aspect of the transverse colon. These bands are shorter than the other coat of the intestine, and serve to produce the sacculi which are characteristic of the cæcum and colon; accordingly, when they are dissected off, the tube can be lengthened, and its sacculated character becomes lost. In the sigmoid colon the longitudinal fibres become more scattered; and round the rectum they spread out and form a layer, which completely encircles this portion of the gut, but is thicker on the anterior and posterior surfaces, where it forms two bands. In addition, two fasciculi of plain muscular tissue arise from the front of the second and third coccygeal vertebrae, and pass downwards and forwards to blend with the longitudinal muscular fibres on the posterior wall of the anal canal. These are known as the *Rectococcygeal muscles*.

The *circular fibres* form a thin layer over the cæcum and colon, being especially accumulated in the intervals between the sacculi: in the rectum they form a thick layer, and in the anal canal they become numerous, and constitute the *Sphincter ani internus*.

The *areolar coat* connects the muscular and mucous layers closely together.

The *mucous membrane*, in the cæcum and colon, is pale, smooth, destitute of villi, and raised into numerous crescentic folds which correspond with the intervals between the sacculi. In the rectum it is thicker, of a darker colour, more vascular, and connected loosely with the muscular coat.

As in the small intestine, the mucous membrane (fig. 1039) consists of a muscular layer, the *muscularis mucosæ*: a quantity of retiform tissue in which the vessels ramify; a basement membrane, and an epithelium which is of the columnar variety and resembles the epithelium found in the small intestine. The mucous membrane of the large intestine presents for examination glands and solitary lymphatic nodules.

The *glands* of the great intestine are minute tubular prolongations of the mucous membrane arranged perpendicularly, side by side, over its entire surface; they are longer, more numerous, and placed in much closer apposition than those of the small intestine;

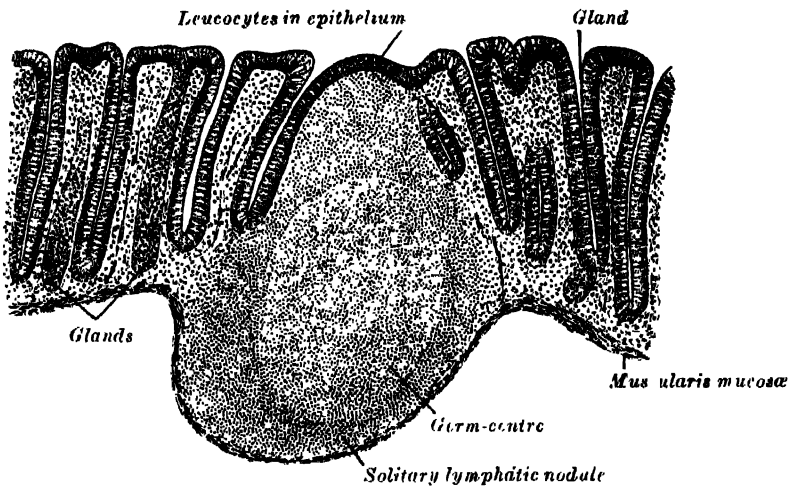
* Footnote, p. 1117.

and they open by minute rounded orifices upon the surface, giving it a cribriform appearance. Each gland is lined by short columnar epithelium, the majority of the cells being goblet cells.

The *solitary lymphatic nodules* (fig. 1039) of the large intestine are most abundant in the cæcum and vermiform process, but are irregularly scattered also over the rest of the large intestine. They are similar to those of the small intestine.

Vessels and Nerves.—The *arteries* supplying the colon are derived from the colic and sigmoid branches of the mesenteric arteries. They give off large branches, which ramify between and supply the muscular coats, and after dividing into small vessels in the sub-mucous tissue, pass to the mucous membrane. The rectum is supplied by the superior hæmorrhoidal branch of the inferior mesenteric, and the anal canal by the middle hæmorrhoidal from the hypogastric, and the inferior hæmorrhoidal from the internal pudendal artery. The superior hæmorrhoidal, the continuation of the superior mesenteric, divides into two branches, which run down either side of the rectum to within about 12·5 cm. of the anus; they here divide into a number of branches, which pierce the muscular coat and descend between it and the mucous membrane in the rectal columns as far as the

FIG. 1039.—A section through the mucous membrane of the human rectum. $\times 60$. (Sobotta.)



Sphincter ani internus, where they anastomose with the other hæmorrhoidal arteries and form a series of loops around the anus. The *veins* of the rectum commence in a plexus of vessels which surrounds the anal canal. In the vessels forming this plexus are small saccular dilatations just within the margin of the anus; from the plexus about six vessels of considerable size are given off. These ascend between the muscular and mucous coats for about 12·5 cm., running parallel to each other; they then pierce the muscular coat, and, by their union, form a single trunk, the superior hæmorrhoidal vein. This arrangement is termed the *hæmorrhoidal plexus*; it communicates with the tributaries of the middle and inferior hæmorrhoidal veins, at its commencement, and thus a communication is established between the systemic and portal circulations. The *nerves* are derived from the sympathetic plexuses around the branches of the superior and inferior mesenteric arteries. They are distributed in a similar way to those found in the small intestine.

The *lymphatics* of the large intestine are described on p. 731.

Applied Anatomy.—The small intestine is much exposed to injury, but, in consequence of its elasticity and the ease with which one coil glides over another, it is not so frequently ruptured as would otherwise be the case. Any part of it may be ruptured, but probably the most common situation is the horizontal portion of the duodenum, on account of its being more fixed than other portions of the bowel, and because it is situated in front of the bodies of the vertebrae, so that if this portion of the intestine is struck by a sharp blow, as from the kick of a horse, it is unable to glide out of the way, but is compressed against the bone and so lacerated. Wounds of the intestine sometimes occur. If the wound is a small puncture, under, it is said, 6 mm. in length, no extravasation of the contents of the bowel takes place: the mucous membrane becomes everted and plugs the little opening. The small intestine, and most frequently the ileum, may become strangulated by internal bands, or through apertures, normal or abnormal. The bands may be formed in several different ways; they may be old peritoneal adhesions from

previous attacks of peritonitis; or an adherent omentum from the same cause; or the band may be formed by Meckel's diverticulum, which has contracted adhesions at its distal extremity; or it may be the result of the abnormal attachment of some normal structure, as the adhesion of two appendices epiploicæ, or an adherent vermiform process or uterine tube. Intussusception, most commonly an invagination of the small intestine into the large, may take place; it may attain great size, and it is possible in these cases to find the colic valve projecting from the anus. Stricture, the impaction of foreign bodies, and twisting of the gut (*volvulus*) may also lead to intestinal obstruction.

Resection of a portion of the intestine may be required in cases of gangrene; for the removal of new-growth in the bowel; in dealing with artificial anus; and in cases of rupture. The operation is termed *enterectomy*, and is performed as follows: the abdomen having been opened and the amount of bowel requiring removal having been determined upon, the intestine must be clamped on either side of this portion in order to prevent the escape of any of its contents during the operation. The portion of the bowel is then separated above and below by means of scissors. If the portion resected is small, it may be simply removed from the mesentery at its attachment, and the bleeding vessels tied; but if it be large it will be necessary to take away a triangular piece of the mesentery, and, having secured the vessels, suture the cut edges of this structure together. In doing this, care must be taken not to leave any intestine projecting beyond the line of the section of the mesentery, as gangrene is very likely to occur in the projecting part if this is done. The surgeon then proceeds to unite the cut ends of the bowel together by end-to-end anastomosis. There are many ways of doing this, but they may be divided into two classes, one where the anastomosis is made by means of some mechanical appliance, such as Murphy's button, or one of the forms of decalcified bone bobbin; and the other, where the operation is performed by suturing the ends of the bowel in such a manner that the peritoneum covering the two divided ends is brought into contact, so that speedy union may ensue.

The vermiform process is very liable to become inflamed, because it contains a relatively large amount of lymphoid tissue which is prone to bacterial infection. In many cases the inflammation is set up by the impaction in it of a solid mass of feces or a foreign body, or by the inspissation of its mucous secretion in catarrhal conditions. The inflammation may result in ulceration and perforation, or if very acute in gangrene of the process. These conditions generally require immediate operative interference, and in chronic cases with recurring attacks of inflammation it is always advisable to remove this diverticulum of the bowel. In making the abdominal wall for this operation, the muscles should be split in the direction of their fibres, rather than cut across, in order to prevent subsequent weakening of the abdominal parietes and the occurrence of a ventral hernia. After the process has been removed it is better to suture the planes of the abdominal wall separately.

In external hernia the ileum is the portion of bowel most frequently herniated. When a part of the large intestine is involved it is usually the cæcum, and this may occur even on the left side. In some few cases the vermiform process has been the part implicated in strangulated hernia.

Chronic ulcer of the duodenum is sometimes met with, probably produced by the same causes as chronic ulcer of the stomach. It may perforate and set up a rapidly fatal peritonitis, or it may open into one of the large duodenal vessels and cause death from hæmorrhage. An acute ulcer sometimes, but rarely, follows extensive burns of the skin.

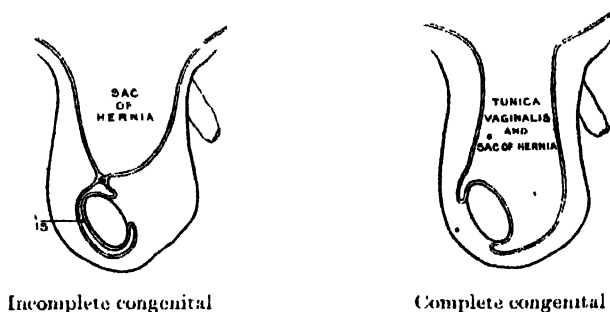
The calibre of the large intestine gradually diminishes from the cæcum, which has the greatest diameter of any part of the bowel, to the point of junction of the sigmoid colon with the rectum. At or a little below this point stricture most commonly occurs, and diminishes in frequency as one proceeds upwards to the cæcum. When distended by some obstruction low down, the outline of the large intestine can be defined throughout nearly the whole of its course—all, in fact, except the right and left colic flexures, which are more deeply placed; the distension is most obvious in the flanks and on the front of the abdomen just above the umbilicus. The cæcum, however, is the portion of the bowel which becomes most distended. It may assume enormous dimensions, and may give way from the distension, leading to rapidly fatal peritonitis. The right colic flexure and the right extremity of the transverse colon are in close relationship with the liver, and abscess of this viscus sometimes bursts into the gut in this situation. The gall-bladder may become adherent to the duodenum or colon, and gall-stones may find their way into either, and may become impacted or may be discharged per anum. The mobility of the sigmoid colon renders it more liable to become the seat of a *volvulus* or twist than any other part of the intestine. This generally occurs in patients who have been the subjects of habitual constipation, and in whom, therefore, the mesocolon is elongated. This portion of the bowel, being loaded with feces, falls over the part below, and so gives rise to the twist.

Hernia.—The two chief sites at which external hernia may take place are the inguinal region and the femoral canal. The description of the inguinal canal and its relations will be found on p. 465 and that of the femoral canal on p. 664. Some points in regard to the disposition of the peritoneum in these regions may, however, be recapitulated here.

Between the upper margin of the front of the pelvis and the umbilicus, the peritoneum, when viewed from behind, will be seen to be raised into five folds, with inter-

vening depressions, by more or less prominent bands which converge to the umbilicus (fig. 1000). The middle umbilical ligament, situated in the middle line, is covered by a fold of peritoneum known as the *middle umbilical fold*. On either side of this a fold of peritoneum round the obliterated umbilical artery forms the *lateral umbilical fold*. To either side of these three cords is the inferior epigastric artery covered by the *epigastric fold*. Between these raised folds are depressions constituting the so-called *foveæ*. The most medial, between the middle and lateral umbilical folds, is known as the *supravesical fovea*. The intermediate one is situated medially to the epigastric fold, and is termed the *medial inguinal fovea*. The third is lateral to the epigastric fold, and is known as the *lateral inguinal fovea*. Occasionally the inferior epigastric artery corresponds in position to the obliterated hypogastric artery, and then there is but one fold on either side of the middle line. In the usual position of the parts, the floor of the lateral inguinal fovea corresponds to the abdominal inguinal ring, and into this fovea an oblique inguinal hernia descends. Medially to the epigastric fold are the medial inguinal and the supravesical foveæ, and through either of these a direct hernia may descend. The whole of the space between the inferior epigastric artery, the margin of the Rectus abdominis, and the inguinal ligament, is known as Hesselbach's triangle. Below the level of the inguinal ligament is a small depression corresponding to the position of the femoral ring. It is known as the *femoral fovea*, and into it a femoral hernia descends.

FIG. 1040.—The varieties of oblique inguinal hernia.



Inguinal hernia.—Inguinal hernia is that form of protrusion which makes its way through the abdominal wall in the inguinal region. There are two principal varieties: lateral or oblique, and medial or direct.

In *oblique inguinal hernia* the intestine escapes from the abdominal cavity at the abdominal inguinal ring, pushing before it a pouch of peritoneum which forms the hernial sac. As it enters the inguinal canal it receives an investment from the extraperitoneal tissue and is enclosed in the infundibuliform fascia. In passing along the inguinal canal it displaces upwards the arched fibres of the Transversus and Obliquus internus, and receives a covering of Cremaster muscle and cremasteric fascia. It then passes along the front of the spermatic cord and escapes from the inguinal canal at the subcutaneous inguinal ring, becoming invested by intercrural fascia. Lastly it descends into the scrotum, receiving coverings from the superficial fascia and the skin.

The seat of stricture in oblique inguinal hernia is at either the abdominal or the subcutaneous inguinal ring; most frequently at the former situation. If it is situated at the subcutaneous ring, the division of a few fibres at one point of the circumference is all that is necessary for the replacement of the hernia. If at the abdominal ring, it is necessary to divide the aponeurosis of the Obliquus externus so as to lay open the inguinal canal; in dividing the aponeurosis the incision should be directed parallel to the inguinal ligament, and the constriction at the abdominal ring should then be divided directly upwards.

When the intestine passes along the inguinal canal and escapes from the subcutaneous ring into the scrotum, it is called a *scrotal hernia*. If the intestine does not pass into the scrotum, but merely bulges through the subcutaneous ring, it is called a *hydrocele*.

The great majority of varieties of oblique inguinal hernia depend upon congenital defects in the saccus vaginalis, the pouch of peritoneum which precedes the descent of the testis. Normally this pouch is closed before birth, closure commencing at two points, viz. at the abdominal inguinal ring and at the top of the epididymis, and gradually extending until the whole of the intervening portion is converted into a fibrous cord. From failure in the completion of this process, variations in the relation of the hernial protrusion to the testis and tunica vaginalis are produced; these constitute distinct varieties of inguinal hernia, viz. the hernia of the funicular process and the complete congenital variety.

Where the sacculus vaginalis remains patent throughout, the cavity of the tunica vaginalis communicates directly with that of the peritoneum. The intestine descends along this pouch into the cavity of the tunica vaginalis, which constitutes the sac of the hernia, and the gut lies in contact with the testis. Though this form of hernia is termed *complete congenital* (fig. 1040), the term does not imply that the hernia existed at birth, but merely that a condition is present which may allow of the descent of the hernia at any moment. As a matter of fact, congenital herniæ frequently do not appear till adult life.

Where the processus vaginalis is occluded at the lower point only, i.e. just above the testis, the intestine descends into the pouch of peritoneum as far as the testis, but is prevented from entering the sac of the tunica vaginalis by the septum which has formed between it and the pouch. This is known as *hernia into the funicular process or incomplete congenital hernia* (fig. 1040); it differs from the former in that instead of enveloping the testis it lies above it.

In *direct inguinal hernia* the protrusion makes its way through some part of Hesselbach's triangle, either through (a) the lateral part, where only extraperitoneal tissue and transversalis fascia intervene between the peritoneum and the aponeurosis of the Obliquus externus; or through (b) the inguinal aponeurotic falx which stretches across the medial two-thirds of the triangle between the artery and the middle line. In the former the hernial protrusion escapes from the abdomen on the lateral side of the inguinal falx, pushes before it the peritoneum, extraperitoneal tissue and transversalis fascia, and enters the inguinal canal. It passes along nearly the whole length of the canal and finally emerges from the subcutaneous ring, receiving an investment from the intercrural fascia. The coverings of this form of hernia are similar to those of the oblique form, except that a portion derived from the general layer of transversalis fascia replaces the infundibuliform fascia.

In the second form, which is the more frequent, the hernia is either forced through the fibres of the inguinal falx, or the falx is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower end of the inguinal canal, escapes at the subcutaneous ring, lying on the medial side of the cord, and receives additional coverings from the intercrural fascia, the superficial fascia and the integument. The coverings of this form therefore differ from those of the oblique form in that the inguinal falx is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion of the general layer of the transversalis fascia.

The seat of stricture in both varieties of direct hernia is usually found either at the neck of the sac or at the subcutaneous ring. In that form which perforates the inguinal falx it may occur at the edges of the fissure through which the gut passes. In all cases of inguinal hernia, whether direct or oblique, it is proper to divide the stricture directly upwards; by cutting in this direction the incision is made parallel to the inferior epigastric artery—laterally to it in the oblique variety, medially to it in the direct form of hernia; all chance of wounding the vessel thus avoided. Direct inguinal hernia is of much less frequent occurrence than oblique, and is found more often in men than in women. The main differences in position between it and the oblique form are: (a) it is placed over the os pubis and not in the course of the inguinal canal; (b) the inferior epigastric artery runs on the lateral or iliac side of the neck of the sac; and (c) the spermatic cord lies along its lateral and posterior sides, not directly behind it as in oblique inguinal hernia. A direct hernia is always of the acquired variety, whereas the oblique form is most commonly due to non-obliteration of part or the whole of the peritoneal pouch which accompanies the testis in its descent, and the sac is therefore most often congenital although the contents may not descend till later in life.

Femoral hernia.—In femoral hernia the protrusion of the intestine takes place through the femoral ring. As already described (p. 654), this ring is closed by the femoral septum, a partition of modified extraperitoneal tissue; it is therefore a weak spot in the abdominal wall, and especially in the female, where the ring is larger, and where profound changes are produced in the tissues of the abdomen by pregnancy. Femoral hernia is therefore more common in women than in men.

When a portion of intestine is forced through the femoral ring, it carries before it a pouch of peritoneum, which forms the hernial sac. It receives an investment from the extraperitoneal tissue or femoral septum, and descends along the femoral canal, or inner compartment of the sheath of the femoral vessels, as far as the fossa ovalis; at this point it changes its course, being prevented from extending farther down the sheath on account of the narrowing of the latter, and its close contact with the vessels, and also the close attachment of the superficial fascia and femoral sheath to the lower part of the circumference of the fossa ovalis. The tumour is consequently directed forwards, pushing before it the fascia cribrosa, and then curves upwards over the inguinal ligament and the lower part of the aponeurosis of the Obliquus externus, being covered by the superficial fascia and integument. While the hernia is contained in the femoral canal it is usually of small size, owing to the resisting nature of the surrounding parts, but when it escapes from the fossa ovalis into the loose areolar tissue of the groin it becomes considerably enlarged. The direction taken by a femoral hernia is at first downwards, then forwards and upwards; in the application of taxis for the reduction of a femoral hernia, therefore, pressure should be directed in the reverse order.

The coverings of a femoral hernia from within outwards are: peritoneum, femoral septum, femoral sheath, fascia cribrosa, superficial fascia, and integument. Sir Astley Cooper has described an investment for femoral hernia under the name of *fascia propria*, lying immediately external to the peritoneal sac but frequently separated from it by some adipose tissue. Surgically it is important to remember the frequent existence of this layer on account of the ease with which an inexperienced operator may mistake the fascia for the peritoneal sac and the contained extraperitoneal fat for omentum, as there is often a great excess of subperitoneal fatty tissue enclosed in the 'fascia propria.' In many cases it resembles a fatty tumour, but on further dissection the true hernial sac will be found in the centre of the mass of fat. The fascia propria is merely a modified femoral septum which has been thickened to form a membranous sheet by the pressure of the hernia.

When the intestine descends along the femoral canal only as far as the fossa ovalis the condition is known as *incomplete* femoral hernia, in contradistinction to the *complete* hernia when it has passed through the fossa ovalis. The small size of the protrusion in the incomplete form of hernia, on account of the firm and resisting nature of the canal in which it is contained, renders it an exceedingly dangerous variety of the disease, from the extreme difficulty of detecting the existence of the swelling, especially in corpulent subjects. The coverings of an incomplete femoral hernia would be from without inwards: integument, superficial fascia, superior cornu of falciform margin of the fossa ovalis, femoral sheath, femoral septum, and peritoneum.

The seat of stricture of a femoral hernia varies: it may be in the peritoneum at the neck of the hernial sac; in the greater number of cases it is at the point of junction of the falciform margin of the fossa ovalis with the free edge of the lacunar ligament; or it may be at the margin of the fossa ovalis. The stricture should in every case be divided in a direction upwards and medialwards for a distance of about 4 mm. to 6 mm. All vessels or other structures of importance in relation to the neck of the sac will thus be avoided.

The pubic tubercle forms an important landmark in serving to differentiate the inguinal from the femoral variety of hernia. The inguinal protrusion is above and medial to the tubercle, while the femoral is below and lateral to it.

There are several details of practical interest in connexion with the mesentery which merit notice. 1. The depth of the mesentery—that is to say, the distance from its parietal to its intestinal attachment—is normally less than 20 cm., generally nearer 15 cm.; but under certain abnormal conditions it may become elongated, and this would appear to favour the occurrence of hernia of the intestine. 2. Not only may the depth of the mesentery be increased, but its point of attachment to the posterior abdominal wall may yield, and descend over the lumbar vertebrae. This condition, which is known under the name of *enteroptosis*, usually occurs in women who have borne many children, and is attended with general relaxation of the abdominal parietes. It produces a characteristic appearance, the abdomen being prominent and pendulous below, while above, it is flattened and constricted. 3. Holes are sometimes present in the mesentery, and these may be congenital, or may be the result of injury. They are of practical importance, since a knuckle of intestine may become herniated into one of them, causing acute strangulation. 4. The lymph-glands contained between the two layers of the mesentery are frequently the seat of tuberculous deposit, especially in children.

Colon.—The colon frequently requires opening in cases of intestinal obstruction, and by some surgeons this operation is performed in cases of cancer of the rectum as soon as the disease is recognised, in the hope that the symptoms may be relieved by removing the irritation produced by the passage of fecal matter over the diseased surface. The operation of *colostomy* may be performed either in the iliac or lumbar region; but *iliac colostomy* has in the present day entirely superseded the lumbar operation. The main reason for preferring this operation is that a spur-shaped process of the mesocolon can be formed, which prevents any fecal matter finding its way past the artificial anus, and the greater ease in maintaining cleanliness. The sigmoid colon being entirely surrounded by peritoneum, a coil can be drawn out of the wound and opened, leaving the attachment of the mesocolon to form a spur, much as it does in an artificial anus caused by sloughing of the intestine after a strangulated hernia, and this prevents any fecal matter finding its way from the gut above the opening into that below. The operation is performed by making an incision 5 cm. to 7 cm. long through the outermost fibres of the left Rectus abdominis, opposite the anterior superior iliac spine. The peritoneum is opened; the sigmoid colon is now sought, pulled out of the wound, and fixed by passing a glass rod beneath it, or by suturing the mesocolon close to the gut to the abdominal wall. Later, the protruding coil of intestine is opened, and finally, when firm adhesions have formed, it is cut completely across.

Rectum.—The surgical anatomy of the rectum is of considerable importance. There may be congenital malformations due to arrest of, or imperfection in, development. Thus, there may be no proctodæal invagination (see p. 139), and consequently a complete absence of the anus; or the hind-gut may be imperfectly developed, and there may be an absence of the rectum, though the anus is developed; or the proctodæal invagination may not communicate with the termination of the hind-gut from want of solution of continuity in the septum which in early fetal life exists between the two.

The mucous membrane of the rectum is thick and but loosely connected to the muscular coat beneath, and thus favours prolapse, especially in children. The vessels of the rectum are arranged, as mentioned above, longitudinally, and are contained in the loose cellular tissue between the mucous and muscular coats, and receive no support from surrounding tissues, and this favours varicosity. Moreover, the veins, after running upwards in a longitudinal direction for about 12.5 cm. in the submucous tissue, pierce the muscular coats, and are liable to become constricted at this spot by the contraction of the muscular wall of the gut. In addition to this there are no valves in the superior hemorrhoidal veins, and the vessels of the rectum are placed in a dependent position, and are liable to be pressed upon and obstructed by hardened feces. The anatomical arrangement, therefore, of the hemorrhoidal vessels explains the great tendency to the occurrence of piles. The presence of the Sphincter ani externus is of surgical importance, since it is the constant contraction of this muscle which prevents an ischio-rectal abscess from healing, and causes it to become a fistula. Also the reflex contraction of this muscle is the cause of the severe pain complained of in fissure of the anus. The relations of the peritoneum to the bowel are of importance in connexion with the operation of removal of the rectum for malignant disease. This membrane gradually leaves the rectum as it descends into the pelvis; first leaving its posterior surface, then the sides, and then the anterior surface, to become reflected, in the male on to the posterior wall of the bladder, forming the rectovesical excavation, and in the female on to the posterior wall of the vagina, forming the recto-uterine excavation. The rectovesical excavation extends to within 7.5 cm. from the anus. Within recent years much more extensive operations have been done for the removal of cancer of the rectum, and in these the peritoneal cavity has necessarily to be opened. For cases of cancer of the rectum which are too low to be reached by abdominal section, and too high to be removed by the perineum, Kraske has devised an operation which goes by his name. The patient is placed on his right side and an incision is made from the last piece of the sacrum to the anus. The coccyx is removed, and if necessary a small piece of the sacrum, and the edges of the wound being now forcibly drawn outwards, a considerable length of the rectum is brought into view, and the diseased portion is removed.

The loose connective tissue round the rectum, above the Levator ani, is occasionally the site of an abscess, the active focus of which, however, may be located elsewhere. This form of abscess may be described as the *superior pelvirectal*; it is placed above the pelvic diaphragm but beneath the peritoneum. The acute variety is generally due to ulceration or perforation of the bowel (possibly produced by a foreign body) above the level of attachment of the Levator ani. The abscess may also occur above a stricture (simple or malignant) of the rectum; occasionally it arises from suppuration around the prostate, and more rarely follows abscess of the vesiculæ seminales. Chronic abscesses also appear in the same region either from caries of the anterior surface of the sacrum or from caseation of the presacral lymph-glands, whilst in other cases an abscess finds its way down into the pelvis from disease of the anterior surfaces of the bodies of the lumbar vertebrae. For abscess in the ischio-rectal fossa, see p. 472.

THE PANCREAS

The **pancreas** is a compound racemose gland, analogous in its structure to the salivary glands, but softer, and less compactly arranged. It is irregularly prismatic in shape, and from 12 cm. to 15 cm. long. Its right extremity, being broad, is called the *head*, and is connected to the main portion, or *body*, of the organ by a slightly constricted part, the *neck*; while its left extremity gradually tapers to form the *tail*. It is placed across the posterior wall of the abdomen, at the back of the epigastrium and left hypochondriac regions.

Relations (figs. 1041 to 1043).—The **head**, flattened from before backwards, is lodged within the curve of the duodenum. Its upper border is overlapped by the superior part of the duodenum; the other borders are grooved to receive the adjacent margin of the duodenum which they there overlap in front and behind to a variable extent. The angle of junction of the lower and left lateral borders forms a prolongation, termed the *uncinate process* which projects to the left behind the superior mesenteric vessels. In or near the groove between the duodenum and the right lateral and lower borders anteriorly are the anastomosing superior and inferior pancreaticoduodenal arteries; the common bile-duct descends behind the head, close to its right border.

Anterior surface.—The upper part of the *right half* of this surface of the head is in contact with the transverse colon, only areolar tissue intervening. The lower part of the right half is covered by peritoneum continuous with the inferior layer of the transverse mesocolon, and is in contact with the coils

of the small intestine. The *neck* springs from the upper part of the *left half*, the right limit of the neck being marked by a groove for the gastroduodenal

FIG. 1041.—A transverse section through the abdomen at the level of the middle of the first lumbar vertebra. (Braune.)

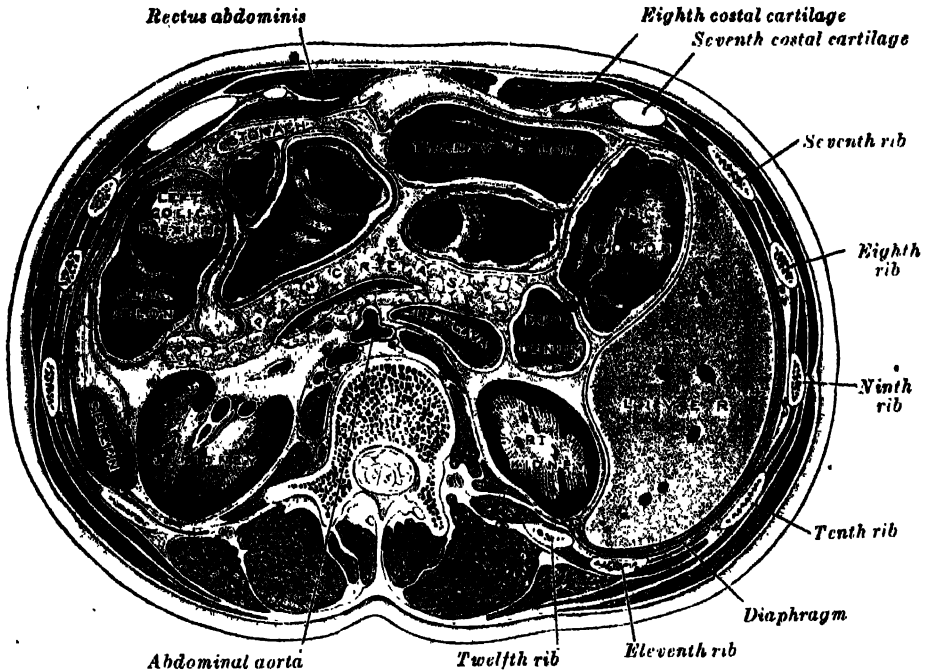


FIG. 1042.—The duodenum and pancreas.



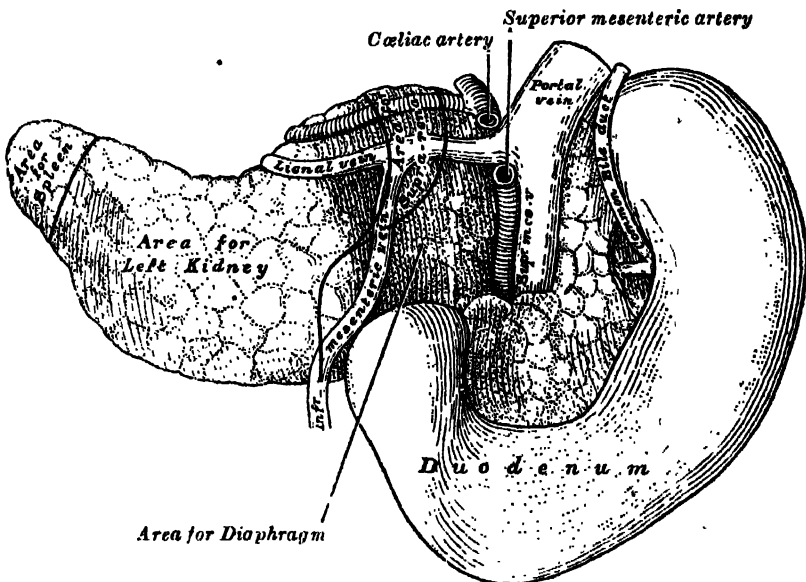
artery. The lower part forms the uncinat process which, as already stated, is crossed by the superior mesenteric vessels. The superior mesenteric vein

runs upwards on the right side of the artery, and, behind the neck, joins with the lienal vein to form the portal vein.

Posterior surface.—The posterior surface of the head is in relation with the inferior vena cava, the renal veins, the right crus of the Diaphragm, and the aorta. The common bile duct either lies in a groove on the posterior surface of the head of the pancreas or in a canal in its substance (McConnell *).

The neck is about 2 cm. long, and is confluent below and to the right with the anterior surface of the head; it extends upwards and to the left, and merges imperceptibly with the body. It is a somewhat ridge-like part of the pancreas, accentuated by two vascular depressions; below and to the left is the deep notch containing the superior mesenteric vessels, while above and to the right is a groove in which the lower end of the gastroduodenal

FIG. 1043.—The pancreas and duodenum. From behind.
(From a model by His.)



artery and its continuation, the superior pancreaticoduodenal artery, are lodged. Its anterior surface supports the pylorus; its posterior surface is in relation with the commencement of the portal vein.

The body is somewhat prismatic in shape, and has three surfaces: anterior, posterior, and inferior.

The anterior surface is somewhat concave, and is directed forwards and upwards; it is separated from the stomach by the omental bursa.

The posterior surface is devoid of peritoneum, and is in contact with the aorta, the lienal vein, the left kidney and its vessels, the left suprarenal gland, the origin of the superior mesenteric artery, and the crura of the Diaphragm.

The inferior surface is narrow on the right but broader on the left, and is covered by peritoneum; it lies upon the duodenojejunal flexure and on some coils of the jejunum; its left extremity rests on the left colic flexure.

The superior border is blunt and flat to the right; narrow and sharp to the left, near the tail. It is in relation with the celiac artery, from which the hepatic artery courses to the right just above the gland, while the lienal artery runs towards the left in a groove along this border. A process, the *tuber omentale*, usually projects from the right end of the superior border above the level of the lesser curvature of the stomach, and is in contact with the hinder aspect of the lesser omentum.

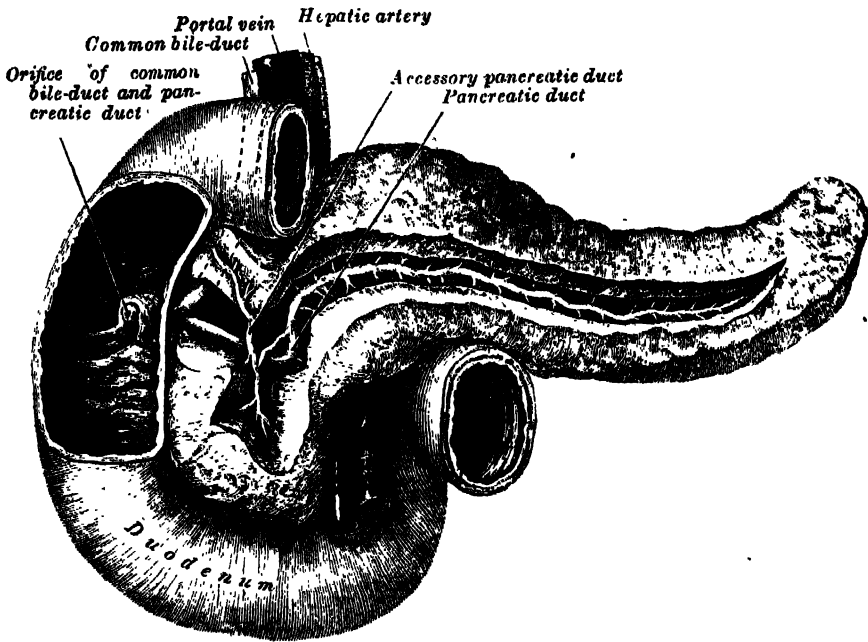
The *anterior border* separates the anterior from the inferior surface, and along this border the two layers of the transverse mesocolon diverge from one another: one passing upwards over the anterior surface, the other backwards over the inferior surface.

The *inferior border* separates the posterior from the inferior surface; the superior mesenteric vessels emerge under its right extremity.

The *tail* is narrow; it projects upwards behind the splenic vessels, coming into contact with the inferior part of the gastric surface of the spleen.

Birmingham described the body of the pancreas as projecting forwards as a prominent ridge into the abdominal cavity and forming part of a bed or shelf on which the stomach lies. 'The portion of the pancreas to the left of the middle line has a very considerable anteroposterior thickness; as a result

FIG. 1044.—The pancreatic duct.



the anterior surface is of considerable extent; it looks strongly upwards, and forms a large and important part of the shelf. As the pancreas extends to the left towards the spleen it crosses the upper part of the kidney, and is so moulded on to it that the top of the kidney forms an extension inwards and backwards of the upper surface of the pancreas and extends the bed in this direction. On the other hand, the extremity of the pancreas comes in contact with the spleen in such a way that the plane of its upper surface runs with little interruption upwards and backwards into the concave gastric surface of the spleen, which completes the bed behind and to the left, and, running upwards, forms a partial cap for the wide end of the stomach.*

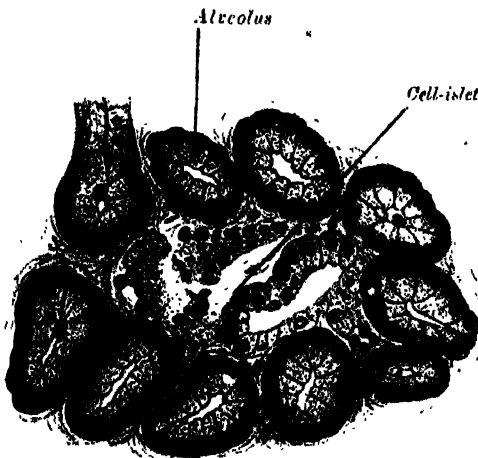
The **pancreatic duct** (ductus Wirsungi) traverses the pancreas from left to right, lying nearer its posterior than its anterior surface (fig. 1044). It commences by the junction of the small ducts of the lobules situated in the tail of the pancreas, and, running from left to right through the body, receives the ducts of the various lobules composing the gland. Considerably augmented in size, it reaches the neck, and turning downwards, backwards, and to the right, comes into relation with the common bile-duct, which lies to its right side; leaving the head of the gland, it passes very obliquely through the mucous and muscular coats of the duodenum, and ends by an orifice common

* *Journal of Anatomy and Physiology*, vol. xxxi. pt. 1, p. 102.

to it and the common bile-duct upon the summit of the duodenal papilla, situated at the medial side of the descending portion of the duodenum, from 7 cm. to 10 cm. beyond the pylorus. The pancreatic duct, near the duodenum, is about the size of an ordinary quill. Sometimes the pancreatic duct and the common bile-duct open separately into the duodenum. Frequently there is an additional duct, which communicates with the pancreatic duct in the neck of the pancreas and opens into the duodenum about 2 cm. above the duodenal papilla. It receives the ducts from the lower part of the head, and is known as the *accessory pancreatic duct* (*ductus Santorini*).

Structure (fig. 1045).—In structure, the pancreas resembles the salivary glands. It differs from them, however, in certain particulars, and is looser and softer in its texture.

FIG. 1045.—A section of the pancreas of a dog. $\times 250$.



It is not enclosed in a distinct capsule, but is surrounded by areolar tissue, which dips into its interior, and connects together the various lobules of which it is composed. Each lobule, like the lobules of the salivary glands, consists of one of the ultimate ramifications of the main duct, ending in a number of alveoli, which are tubular and somewhat convoluted. The minute ducts (intercalary ducts) connected with the alveoli are narrow and lined with flattened cells. In some animals spindle-shaped cells occupy the centre of the alveolus and are known as *centro-acinar cells*. These are prolongations of the terminal ducts. The true secreting cells which line the wall of the alveolus are columnar in shape and present two zones: an outer one, clear and faintly striated, next the basement membrane, and an inner one which contains secretory granules. In

hardened specimens the outer zone stains deeply with basic dyes, whereas the inner zone stains slightly. During activity the granular zone gradually diminishes in size; during the resting stages it gradually increases until it forms nearly three-fourths of the cell. In some of the secreting cells of the pancreas is a spherical mass, staining more easily than the rest of the cell; this is termed the *paranucleus*, and is believed to be derived from the nucleus. Between the alveoli are found, in certain parts, collections of cells, which are termed *interalveolar cell-islets*, or *islands of Langerhans*. The cells of these stain lightly with hematoxylin or carmine, and are more or less polyhedral in shape, forming a network in which many capillaries ramify. There are two main types of cell in the islets, distinguished as A-cells and B-cells according to the special staining reactions of the granules they contain. The cell-islets have been supposed to produce the internal secretion of the pancreas which is necessary for carbohydrate metabolism, but numerous researches have so far failed to elucidate their real function.

The wall of the pancreatic duct is thin, consisting of two coats, an external fibrous and an internal mucous; the latter is smooth, lined by columnar epithelium, and furnished near its termination with a few scattered follicles.

Vessels and Nerves.—The arteries of the pancreas are derived from the lienal artery, and from the pancreaticoduodenal branches of the hepatic and superior mesenteric arteries. Its veins open into the lienal and superior mesenteric veins. Its lymphatic vessels are described on p. 732. Its nerves are filaments from the lienal plexus.

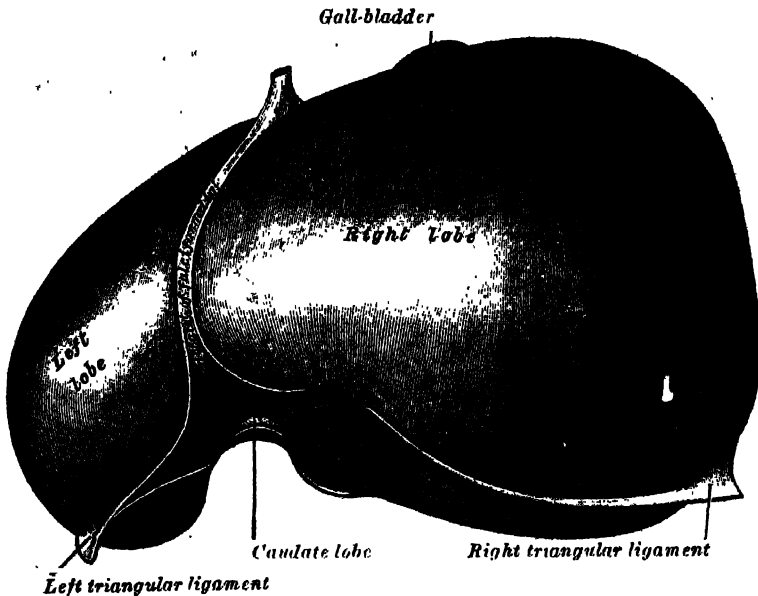
Applied Anatomy.—Inflammation of the pancreas has of late years received considerable attention. It appears to be due to infection of the pancreatic ducts by micro-organisms from the duodenum in cases of gastroduodenal catarrh, or from the biliary passages in which a gall-stone is lodged. Acute cases usually terminate fatally and are frequently of the hemorrhagic type; chronic inflammation of the pancreas produces few symptoms of disease unless it is extensive, when attacks of abdominal pain, loss of appetite, progressive weakness and wasting, and the passage of whitish fatty motions, are likely to follow. Extensive fibrosis of the pancreas is also one of the commonest lesions found post-mortem in cases of diabetes mellitus. Cysts of the pancreas are sometimes met with. They may be the result of traumatism, when they generally contain blood, or they may be due to retention from obstruction of a duct, or from pressure on the main duct by a gall-stone. They may attain a large size, and cause symptoms by pressing on the stomach, Diaphragm, or common bile-duct. They generally push their way for-

wards between the stomach and transverse colon, and may then be felt as a definite tumour in the middle line of the upper part of the abdomen. The tumour is fixed and does not move with respiration. The treatment consists in opening the abdomen in the middle line, incising the cyst, evacuating its contents, and fixing its walls to the deeper layers of the abdominal wall. Drainage in the left loin, just below the last rib, can sometimes be established. When they are situated in the tail of the pancreas they have been removed. The pancreas is often the seat of cancer; this usually affects the head, and therefore speedily involves the common bile-duct, leading to persistent jaundice; or it may press upon the portal vein, causing ascites, or involve the stomach, causing pyloric obstruction. It has been said that the pancreas is the only abdominal viscus which has never been found in a hernial protrusion; but even this organ has been found in company with other viscera, in rare cases of diaphragmatic hernia.

THE LIVER (HEPĀR).

The liver, the largest gland in the body, is situated in the upper and right parts of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and not uncommonly

FIG. 1046.—The superior, anterior, and right lateral surfaces of the liver.
(From a model by His.)



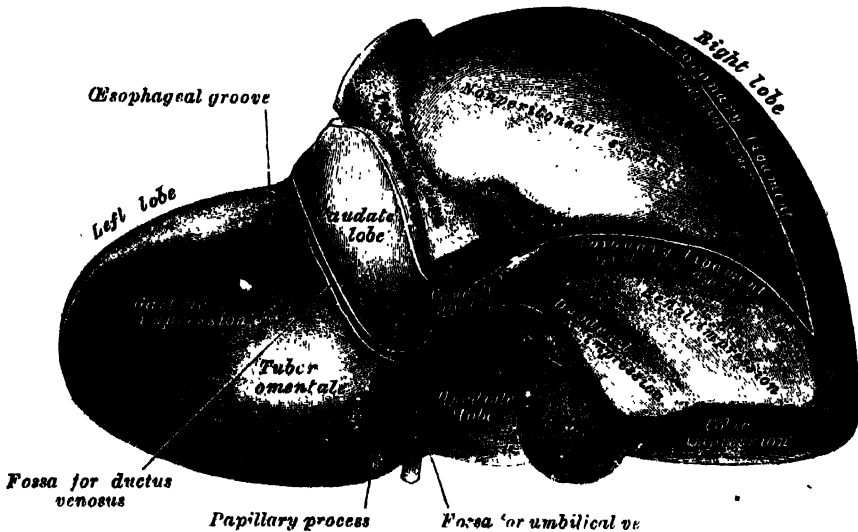
extending into the left hypochondrium as far as the mammary line. In the male it weighs from 1.4 to 1.6 kilogram., in the female from 1.2 to 1.4 kilogram. It is relatively much larger in the foetus than in the adult, constituting, in the former, about one-eighteenth, and in the latter, about one-thirty-sixth of the entire body weight. Its greatest transverse measurement is from 20 cm. to 22 cm. Vertically, near its lateral or right surface, it measures from 15 cm. to 17 cm., while its greatest anteroposterior diameter is on a level with the upper end of the right kidney, and is from 10 cm. to 12 cm.; opposite the vertebral column its measurement from before backwards is reduced to about 7 cm. Its consistence is that of a soft solid; it is, however, friable and easily lacerated; its colour is a dark reddish-brown, and its specific gravity is 1.05.

When the liver has been hardened *in situ* it presents the appearance of a wedge, the base of which is directed to the right and the edge to the left. Symington describes its shape as that of a right-angled triangular prism with the right angles rounded off.

The liver possesses five surfaces, viz. superior, inferior, anterior, posterior, and right. The inferior is separated from the superior, anterior, and right surfaces by a sharp margin, but the superior, anterior, and right surfaces are united by round borders. A sickle-shaped fold of peritoneum, named the falciform ligament, is attached by its convex edge to the Diaphragm and the anterior abdominal wall, and by its concave edge to the anterior and superior surfaces of the liver which it divides into a large right and a small left lobe (fig. 1046). In the free edge of this ligament there is a round cord, the *ligamentum teres hepatis*, which consists of the obliterated left umbilical vein.

Fossæ.—The inferior and posterior surfaces of the liver (figs. 1047, 1048) are traversed by five fossæ or fissures, arranged somewhat like the letter H. The left limb of the H is formed by the *left sagittal fossa*, which here separates the right and left lobes; it consists of an anterior part, the fossa for the umbilical vein, and a posterior part, the fossa for the ductus venosus. The right limb

FIG. 1047.—The posterior and inferior surfaces of the liver.
(From a model by Ilis.)



of the H is formed by the *right sagittal fossa*, the anterior of which is the fossa for the gall-bladder, the posterior, the fossa for the inferior vena cava. The cross-bar of the H is represented by the porta hepatis.

The *fossa for the umbilical vein* (fig. 1047) is a deep cleft which runs backwards from a notch (*incisura umbilicalis*) on the anterior margin of the liver to the left end of the porta hepatis, where it joins the fossa for the ductus venosus. It forms the left boundary of a four-sided area named the quadrate lobe, and a part of it is often bridged by a band of liver-substance, named the *pons hepatis*. In the foetus it lodges the left umbilical vein, and in the adult, the obliterated remains of this vein, viz. the *ligamentum teres hepatis*.

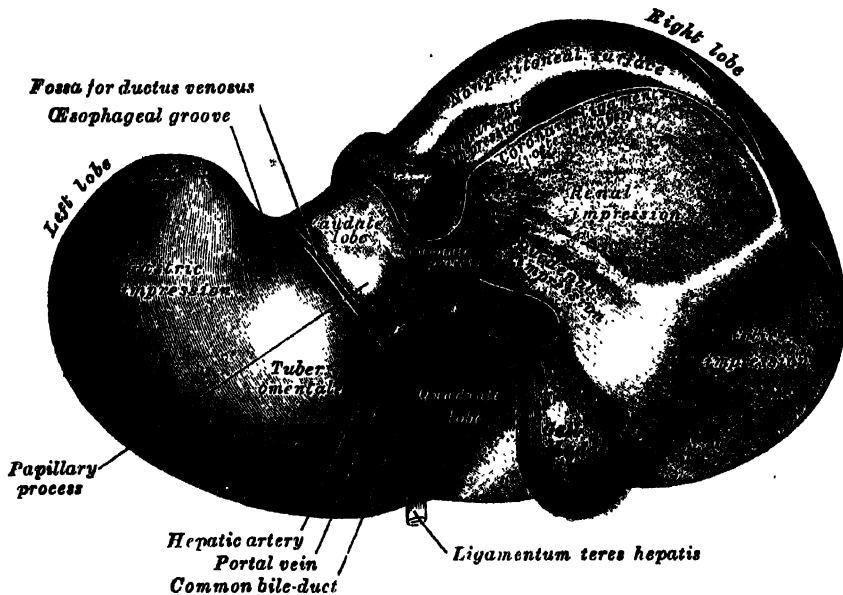
The *fossa for the ductus venosus* (fig. 1047) is a deep cleft on the posterior surface of the liver, separating the left lobe from an oblong area, named the caudate lobe. In the foetus it lodges the ductus venosus, and in the adult, a part of the lesser omentum, and a slender cord, named the *ligamentum venosum*, which represents the obliterated remains of the duct. The *ligamentum venosum* runs upwards and towards the right, in front of the upper end of the caudate lobe, and is attached to the wall of the inferior vena cava.

The *fossa for the gall-bladder* (fig. 1048) is a shallow depression on the inferior surface of the right lobe, parallel with, but on the right of, the fossa for the umbilical vein. It extends from the anterior margin of the liver, which is often notched by it, to the right extremity of the porta hepatis, and forms the right limit of the quadrate lobe.

The *fossa for the inferior vena cava* (fig. 1047) is a deep depression, occasionally a complete tunnel, on the posterior surface of the liver, between the caudate lobe and what is known as the 'bare area' of the right lobe (p. 1136). It is separated from the porta hepatis by a narrow band of liver-substance, named the *caudate process*. If the inferior vena cava be slit open the orifices of the hepatic veins will be displayed.

The *porta hepatis* (transverse fissure) (fig. 1048) is a deep fissure about 5 cm. long. It runs transversely between the posterior ends of the fossæ for the gall-bladder and umbilical vein, and separates the quadrate from the caudate lobe. Through the porta hepatis the portal vein, the hepatic artery and a plexus of nerves enter, and the right and left hepatic ducts and some lymphatic vessels leave, the liver. Near the right end of the porta hepatis the right and left hepatic ducts unite, at an obtuse angle, to form the hepatic duct. The hepatic duct and artery are placed in front of the portal vein, the duct lying

FIG. 1048.—The inferior surface of the liver. (From a model by His.)



on the right side of the artery. The lesser omentum is attached to the margins of the porta hepatis.

Lobes.—As already stated, the falciform ligament and the left sagittal fossa serve to divide the liver into a right and a left lobe.

The *left lobe* is thin, flattened from above downwards, and only about one-sixth of the size of the right. It presents superior, inferior and posterior surfaces which are described with the surfaces of the liver.

The *right lobe* is of a somewhat quadrilateral form. The porta hepatis and the fossæ for the gall-bladder and inferior vena cava traverse its posterior and inferior surfaces and divide its left portion into two smaller lobes, named the quadrate and caudate.

The *quadrate lobe* (figs. 1047, 1048) is situated on the inferior surface of the liver. It is bounded in front by the anterior margin, behind by the porta hepatis, on the right by the fossa for the gall-bladder, and on the left by the fossa for the umbilical vein. It is oblong in shape, its anteroposterior diameter being greater than its transverse.

The *caudate lobe* (Spigelian lobe) (fig. 1047) is situated on the posterior surface of the liver, opposite the lower three thoracic vertebræ. It is bounded above by the upper part of the ligamentum venosum, below by the porta hepatis, on the right by the fossa for the inferior vena cava, and on the left by the fossa for the ductus venosus. It has two free surfaces; one, quadrilateral in

shape, directed backwards and a little to the left, is separated from the Diaphragm by the superior recess of the omental bursa (p. 1092), the other, directed forwards and to the left, forms the right wall of the fossa for the ductus venosus, and is in contact with the part of the lesser omentum which lies in this fossa. A notch divides the projecting lower end of the lobe into a rounded left part, named the *papillary process*, and a narrow right part, termed the *caudate process*. The latter separates the porta hepatis from the fossa for the inferior vena cava, and connects the caudate lobe with the inferior surface of the main part of the right lobe (fig. 1048).

Surfaces.—The *superior surface* of the liver (fig. 1046) includes portions of the right and left lobes. It fits under the vault of the Diaphragm, and is covered by peritoneum, with the exception of a small triangular area between the diverging layers of the falciform ligament. Its right and left portions are convex, but on its central part there is a shallow *cardiac impression* which corresponds with the position of the heart on the upper surface of the Diaphragm.

The *anterior surface*, triangular in shape, also comprises portions of the right and left lobes, and is covered by peritoneum except at the line of attachment of the falciform ligament. A large part of this surface is in contact with the Diaphragm, which separates it on the right side from the sixth to the tenth ribs and their cartilages, and on the left side from the seventh and eighth costal cartilages. Its central part lies behind the xiphoid process of the sternum and, in the angle between the diverging right and left costal cartilages, the anterior abdominal wall.

The *right surface* is convex from before backwards, and slightly so from above downwards. It is covered by peritoneum and lies against the right portion of the Diaphragm which separates it from the lower parts of the right lung and pleura; outside these are the right costal arches from the seventh to the eleventh inclusive.

The *posterior surface* (fig. 1047) includes portions of the right and left lobes, and is thick and convex on the right, but thin on the left. Its central part is deeply concave in adaptation to the convexity formed by the vertebral column and the crura of the Diaphragm. A large part of this surface of the right lobe is not covered by peritoneum but is attached to the Diaphragm by areolar tissue. This non-peritoneal surface, or 'bare area' as it is termed, is triangular in shape, and is limited above and below by the superior and inferior layers of the coronary ligament. Its base is formed by the fossa for the inferior vena cava, while its apex, directed downwards and lateralwards, corresponds with the meeting-point of the two layers of the coronary ligament. Immediately to the right of the lower part of the fossa for the inferior vena cava is a small triangular pit, the greater part of which is on the bare surface; it lodges the right suprarenal gland and is named the *suprarenal impression*. Between the fossæ for the inferior vena cava and the ductus venosus is the caudate lobe, already described. Immediately to the left of the fossa for the ductus venosus, on the posterior surface of the left lobe, is the *œsophageal impression* in which the antrum cardiacum of the œsophagus is lodged.

The *inferior or visceral surface* (fig. 1048) is concave but uneven. It is directed downwards, backwards and towards the left, and is in contact with the stomach, duodenum, lesser omentum, right colic flexure, right kidney and right suprarenal gland. It is invested by peritoneum, except at the fossa for the gall-bladder and at the porta hepatis. On the inferior surface of the left lobe, and in direct continuity with the œsophageal groove, is the *gastric impression* which is moulded over the stomach. On the right of this impression is a rounded eminence, the *tuber omentale*; this fits into the concavity of the lesser curvature of the stomach, and is in contact with the lesser omentum. On the right of the fossa for the umbilical vein is the quadrate lobe which is concave and lies over the pyloric part of the stomach and the beginning of the duodenum, when these are dilated. When, on the other hand, the stomach is empty the quadrate lobe is in contact with the superior part of the duodenum and a portion of the transverse colon. Behind the quadrate lobe are the porta hepatis and the papillary and caudate processes, already described. There are three impressions, colic, renal and duodenal, on the part of the right lobe which is placed on the right side of the fossa for the gall-bladder. The *colic impression*, produced by the right colic flexure, is shallow and is situated anteriorly. The *renal impression*,

posterior to and deeper than the colic impression, is occupied by the upper part of the right kidney, and frequently extends for a short distance on to the lower part of the 'bare area.' The *duodenal impression* is between the renal impression and the neck of the gall-bladder. It is a narrow concave surface which comes into contact with the descending part of the duodenum.

The *anterior margin* of the liver is sharp, and marked, opposite the attachment of the falciform ligament by the incisura umbilicalis, and frequently by a second notch opposite the fundus of the gall-bladder. In adult males this margin generally corresponds with the lower edge of the thorax in the right mammary line, but in women and children it usually projects below the ribs.

Ligaments.—The liver is connected to neighbouring structures by ligaments. These, except the ligamentum teres hepatis and the ligamentum venosum, consist of folds or reflections of the peritoneum and comprise the falciform, coronary, right and left triangular, hepatogastric and hepatoduodenal ligaments.

The *falciform ligament* connects the liver to the Diaphragm and to the anterior abdominal wall and is a sickle-shaped fold consisting of two layers of peritoneum closely united together. Its convex margin is fixed to the inferior surface of the Diaphragm, and to the anterior abdominal wall as low as the umbilicus. Its concave margin is attached to the anterior and superior surfaces of the liver and to the fossa for the umbilical vein on its inferior surface. In its base or free edge are contained the ligamentum teres hepatis and the small paraumbilical veins. At the posterior part of the superior surface of the liver the two peritoneal layers of the falciform ligament separate from one another and expose a small triangular area which is uncovered by peritoneum. The right layer of the ligament is continuous with the superior layer of the coronary ligament, the left with the anterior layer of the left triangular ligament (fig. 1046).

The *coronary ligament* (fig. 1047) is formed by the reflections of the peritoneum from the liver to the Diaphragm at the upper and lower boundaries of the 'bare area,' and consists of a superior layer which is continuous with the right layer of the falciform ligament, and an inferior layer which passes on to the right kidney and suprarenal gland and is termed the *hepatorenal ligament*.

The *right triangular ligament* (right lateral ligament) (fig. 1046) is situated at the right extremity of the 'bare area,' and is a small fold which passes to the Diaphragm. It is formed by the apposition of the two layers of the coronary ligament.

The *left triangular ligament* (left lateral ligament) (fig. 1046) is larger than the right. It connects the posterior part of the upper surface of the liver to the Diaphragm, and its anterior layer is continuous with the left layer of the falciform ligament.

The *hepatogastric* and *hepatoduodenal* ligaments together constitute the lesser omentum which is attached below to the lesser curvature of the stomach and the superior part of the duodenum, and above to the liver along the margins of the porta hepatis and at the bottom of the fossa for the ductus venosus. Between the layers of the hepatoduodenal ligament are contained the common bile-duct, the portal vein and the hepatic artery, together with some lymph-glands and lymphatic vessels, and a plexus of nerves.

The *ligamentum teres hepatis* (fig. 1048) is a fibrous cord resulting from the obliteration of the left umbilical vein of the foetus. It runs from the umbilicus upwards and backwards in the free margin of the falciform ligament to the incisura umbilicalis, and above this in the fossa for the umbilical vein to the porta hepatis where it joins the left branch of the portal vein. Before birth the left umbilical vein conveyed blood from the placenta to the foetus.

The *ligamentum venosum* (*Arantii*) is a fibrous cord resulting from the obliteration of the ductus venosus. It ascends in the fossa for the ductus venosus and unites the left branch of the portal vein to the terminal part of the inferior vena cava. Before birth the ductus venosus transmitted to the inferior vena cava some of the blood conveyed from the placenta by the left umbilical vein.

Vessels and Nerves.—The vessels connected with the liver are the portal vein, and the hepatic artery and veins.

The *portal vein* and *hepatic artery*, accompanied by numerous nerves, ascend between the layers of the lesser omentum to the porta hepatis where each divides into two branches; the *bile-duct* and *lymphatic vessels* descend from the porta hepatis between

the layers of the same omentum. They are all enveloped in a loose areolar tissue, the *fibrous capsule of Glisson*, which accompanies the vessels in their course through the portal canals in the interior of the liver (fig. 1050).

The *hepatic veins* (fig. 1049) convey the blood from the liver to the inferior vena cava, and are described on p. 708. They have very little cellular investment, but what there is

FIG. 1049.—A longitudinal section of a hepatic vein. (After Kiernan.)

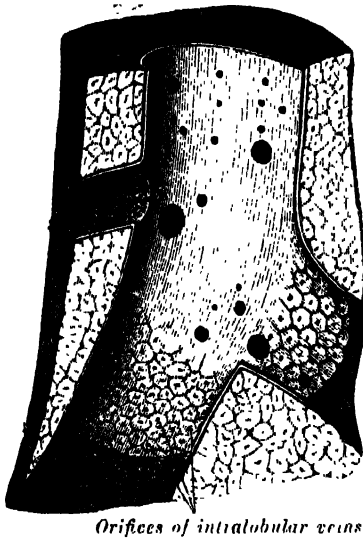
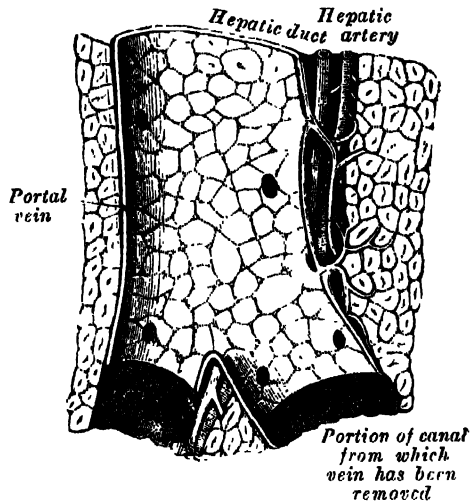


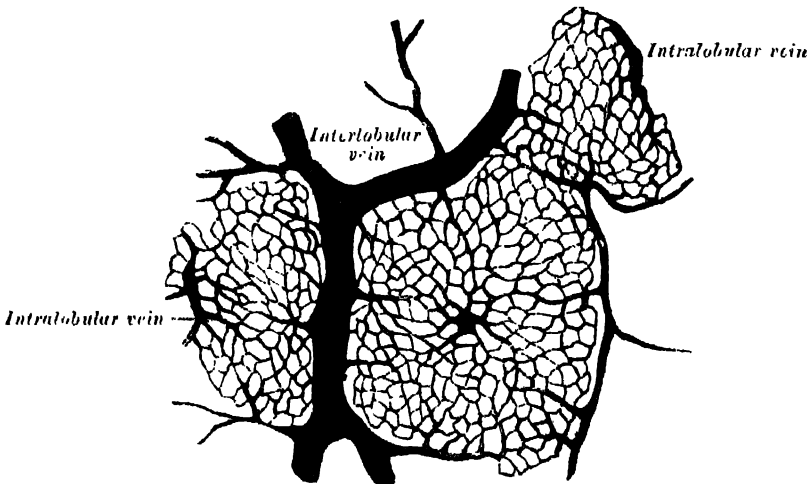
FIG. 1050.—A longitudinal section of a small portal vein and canal. (After Kiernan.)



binds them closely to the walls of the canals through which they run: so that, on section of the liver, they remain widely open and are solitary, and may be easily distinguished from the branches of the portal vein, which are more or less collapsed, and always accompanied by an artery and duct.

The *lymphatic vessels* of the liver are described on p. 731.

FIG. 1051.—A section of the injected liver (dog).



The *nerves* of the liver, derived from the *left vagus* and *sympathetic*, enter at the porta hepatis and accompany the vessels and ducts to the interlobular spaces. Here, according to Korolkow, the medullated fibres are distributed almost exclusively to the coats of the blood-vessels; while the non-medullated enter the lobules and ramify between the cells.

Structure of the Liver.—The liver is dark reddish-brown in colour and is covered by peritoneum, underneath which is a thin capsule of connective tissue. With the naked eye the liver can be seen to consist of an enormous number of polyhedral lobules (fig.

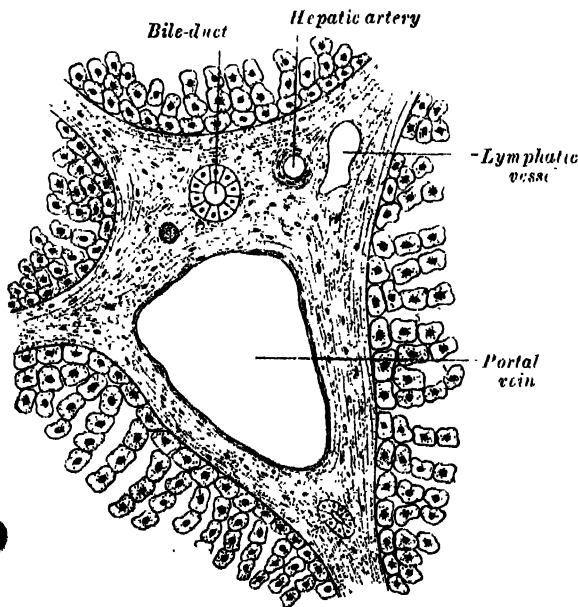
1052), each of which is about 1 mm. in diameter. In the pig each lobule is sharply marked off from those adjoining it by connective tissue septa, but in the human liver there are no such definite boundaries.

A *lobule* consists of a mass of cells, arranged in columns which radiate from a central vein (fig. 1052). Between the columns are irregular blood-vessels (*sinusoids*).

A *liver-cell* is approximately cubical in shape, and is from 12μ to 25μ in diameter. It possesses one or two spherical *nuclei*, and its protoplasm usually contains granules of *glycogen*, and of a compound of *iron*. Fat droplets may also be present in the liver-cell.

Blood is conveyed to the liver by the portal vein and hepatic artery. These vessels enter the liver at the porta hepatis, and, as already stated, are enclosed together with the hepatic duct in a connective tissue sheath termed Glisson's capsule. In the porta hepatis the portal vein, hepatic artery and duct each divide into right and left branches, and these branches subsequently ramify, in their connective tissue capsule, throughout the substance of the liver, and are accompanied by nerves and lymphatic vessels. The spaces occupied by these various structures are named *portal canals* (fig. 1053). The smallest branches of the portal vein form *interlobular plexuses* between the liver lobules, and from these plexuses capillary-like vessels, named *sinusoids*, run between the columns of liver-cells and open into the *intralobular veins* in the centres of the lobules. The intra-lobular veins join to form *sublobular veins*, and these unite to form the *hepatic veins* (fig. 1049) which drain the blood from the liver into the inferior vena cava.

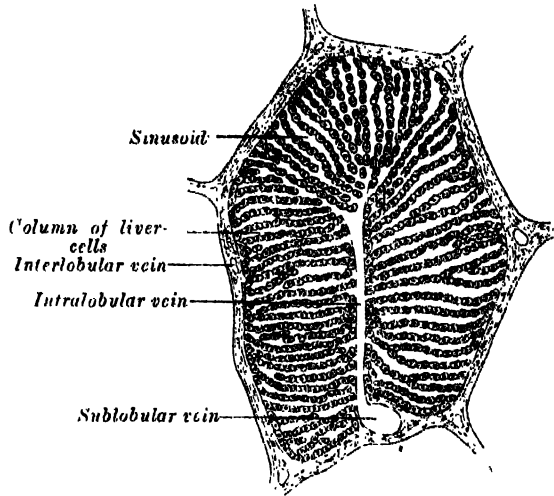
FIG. 1053.—A section across a portal canal of a pig. $\times 250$.



according to Herring and Simpson, minute channels penetrate the liver-cells, conveying the constituents of the blood into their substance.

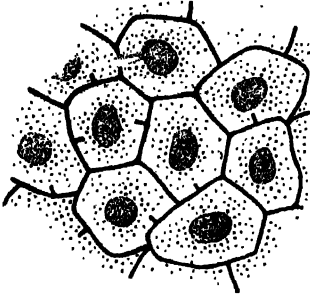
The *bile-ducts* do not penetrate the lobules, but receive minute canaliculi which convey the bile from the cells to the periphery of the lobules. These canaliculi, or *bile-capillaries*, are merely little channels or spaces between adjacent cells, and are always separated from the sinusoids by at least half the width of a liver-cell (fig. 1054).

FIG. 1052.—A section across a lobule of a pig's liver. $\times 60$.



Structure of the ducts.—The walls of the biliary ducts consist of a connective tissue coat, in which are non-striped muscle-cells arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells resting on a basement membrane.

FIG. 1054.—The bile-capillaries of a rabbit, shown by Golgi's method. $\times 450$.



Nerve-fibrils are said to be distributed between the cells of the liver lobules, and even to enter their substance.

EXCRETORY APPARATUS OF THE LIVER

The excretory apparatus of the liver consists of (1) the *hepatic duct*, formed by the junction of the two main ducts, which leave the liver at the porta hepatis; (2) the *gall-bladder*, which serves as a reservoir for the bile; (3) the *cystic duct*, or duct of the gall-bladder; and (4) the *common bile-duct*, formed by the junction of the hepatic and cystic ducts.

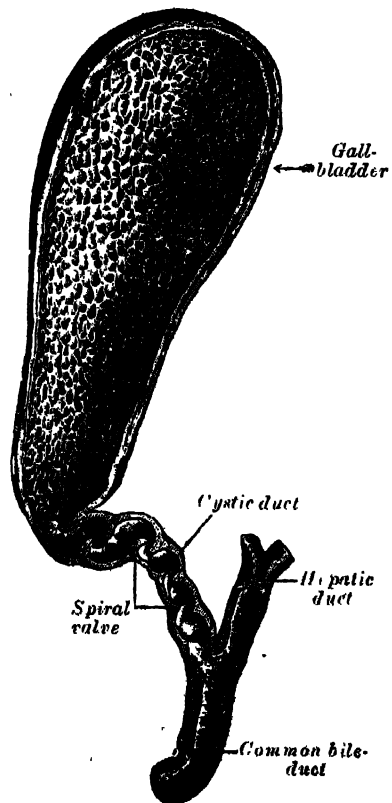
The hepatic duct.—Two main ducts (right and left hepatic) issue from the liver at the porta hepatis and unite to form the hepatic duct, which passes downwards for about 3 cm., and is joined at an acute angle by the cystic duct; by the union of the two ducts the common bile-duct is formed. The hepatic duct is on the right of the hepatic artery and in front of the portal vein.

The gall-bladder (*vesica fellea*) (fig. 1055) is a conical or pear-shaped sac, lodged in a fossa on the under surface of the right lobe, and extending from near the right extremity of the porta hepatis to the anterior border of the liver. It is from 7 cm. to 10 cm. in length, 3 cm. in breadth at its widest part, and holds from 30 c.cm. to 50 c.cm. It is divided into a fundus, body, and neck. The *fundus*, or expanded end, is directed downwards, forwards, and to the right, and projects beyond the anterior border of the liver; the *body* is directed upwards, backwards, and to the left. The upper surface of the gall-bladder is attached to the liver by connective tissue and vessels; the under surface and sides are covered by peritoneum, which is continued from the surface of the liver. Occasionally the gall-bladder is completely invested by peritoneum, and may be connected to the liver by a short mesentery.

Relations.—The *body* of the gall-bladder is in relation, by its upper surface, with the liver; by its under surface, with the commencement of the transverse colon; and farther back usually with the upper end of the descending portion of the duodenum, but sometimes with the superior portion of the duodenum or pyloric end of the stomach. The *fundus*

is completely invested by peritoneum; it is in relation, in front, with the abdominal parietes, immediately below the ninth costal cartilage; behind with the transverse colon. The *neck* is narrow; it curves upwards and forwards, and then, turning abruptly backwards and downwards, becomes continuous with the cystic duct; at its point of continuity with the cystic duct it presents

FIG. 1055.—The gall-bladder and bile-ducts laid open. (Spalteholz.)



a constriction. The neck is attached to the liver by areolar tissue in which the cystic artery is imbedded. Below the neck is the superior part of the duodenum.

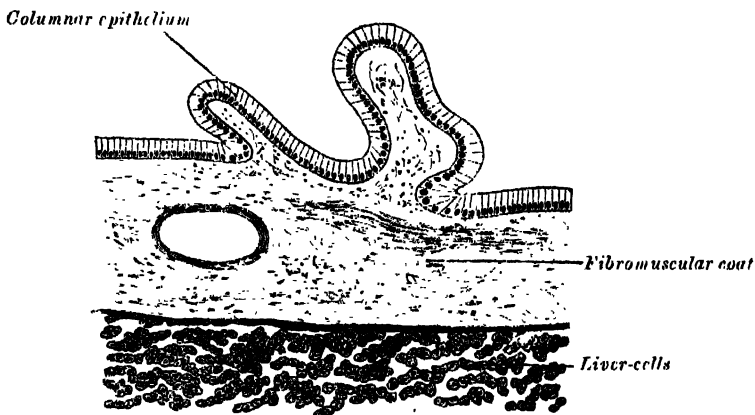
Structure (fig. 1056).—The gall-bladder has three coats: serous, fibromuscular, and mucous.

The *external or serous coat* is derived from the peritoneum; it completely invests the fundus, but covers only the under surfaces and sides of the body and neck.

The *fibromuscular coat*, a thin but strong layer, consists of dense fibrous tissue, mixed with plain muscular fibres, which are disposed chiefly in a longitudinal direction, a few running transversely.

The *internal or mucous coat* is loosely connected with the fibrous layer. It is generally of a yellowish-brown colour, and is elevated into minute rugæ. Opposite the neck of the gall-bladder the mucous membrane projects inwards in the form of oblique ridges or folds, forming a sort of spiral valve. The mucous membrane is continuous through the hepatic duct with that of the ducts of the liver, and through the common bile-duct with that of the duodenum. Its epithelium is columnar, and secretes mucin, or, in some animals, a nucleoprotein.

Fig. 1056.—A transverse section of the wall of the gall-bladder.



The **cystic duct**, from 3 cm. to 4 cm. long, passes backwards, downwards, and to the left from the neck of the gall-bladder, and joins the hepatic duct to form the common bile-duct. The cystic duct runs parallel with and adheres to the hepatic duct for a short distance before joining with it. The mucous membrane lining its interior is thrown into a series of crescentic folds, from five to twelve in number, similar to those found in the neck of the gall-bladder. They project into the duct in regular succession, and are directed obliquely round the tube, presenting much the appearance of a crescentic spiral valve. When the duct is distended, the spaces between the folds are dilated, and the exterior of the duct appears twisted.

The **common bile-duct** (*ductus choledochus*) is formed by the junction of the cystic and hepatic ducts; it is about 7 cm. long, and of the diameter of a goose-quill.

It runs at first downwards, backwards, and to the left in the right border of the lesser omentum, in front of the portal vein, and on the right of the hepatic artery. It passes behind the superior portion of the duodenum, and then runs in a groove, on the posterior surface of the head of the pancreas; here it is situated in front of the inferior vena cava, and is sometimes completely imbedded in the pancreatic substance. Its terminal part lies for a short distance along the right side of the terminal part of the pancreatic duct and passes with it obliquely through coats of the duodenum. The two ducts unite and open by a common orifice upon the summit of a papilla, situated at the medial side of the descending portion of the duodenum, 7 cm. to 10 cm. from the pylorus (fig. 1044). The short tube formed by the union of the two ducts is dilated into an ampulla, the ampulla of Vater.

Structure.—The coats of the large biliary ducts are an external or fibrous, and an internal or mucous. The fibrous coat is composed of strong fibro-areolar tissue, with a certain amount of muscular tissue, arranged, for the most part, in a circular manner around the duct. The mucous coat is continuous with the lining membrane of the hepatic ducts and gall-bladder, and also with that of the duodenum; and, like the mucous membrane of these structures, its epithelium is of the columnar variety. It is provided with numerous mucous glands, which are lobulated and open by minute orifices scattered irregularly in the larger ducts.

Applied Anatomy.—On account of its large size, its fixed position, and its friability, the liver is more frequently ruptured than any of the other abdominal viscera. The rupture may vary from a slight scratch to an extensive and complete laceration of its substance, dividing it into two parts. Sometimes an internal rupture, without laceration of the peritoneal covering, takes place, and such injuries are most susceptible of repair; but small tears of the surface may also heal; when, however, the laceration is extensive, death usually takes place from hæmorrhage, on account of the fact that the hepatic veins are contained in rigid canals in the liver-substance and are unable to contract, and are moreover unprovided with valves. The liver may also be torn by the end of a broken rib perforating the Diaphragm. It may be injured by stabs or other punctured wounds, and when these are inflicted through the chest-wall, the pleural and peritoneal cavities may both be opened up, and both lung and liver wounded. In cases of laceration of the liver, when there is evidence that bleeding is going on, the abdomen must be opened, the laceration sought for, and the bleeding arrested. This may be done temporarily by introducing the forefinger into the epiploic foramen and placing the thumb on the lesser omentum, and compressing the hepatic artery and portal vein between the two. The margins of the laceration, if small, can be brought together and sutured by means of a blunt curved needle passed from one side of the wound to the other; this must be done with the greatest gentleness, as the liver substance is very friable. When the laceration is extensive it must be packed with gauze, the end of which is allowed to hang out of the external wound.

Abscess of the liver is of not infrequent occurrence. The so-called *tropical abscess* is due to absorption, from the intestine, of the amœba of dysentery, which reaches the liver through the portal system and causes the formation of a large chronic abscess; this may enlarge in many different directions on account of the relations of the liver to other organs. Thus it has been known to burst into the lungs, when the pus is coughed up; or into the stomach, when the pus is vomited; it may burst into the colon, or duodenum; or, by perforating the Diaphragm, it may empty itself into the pleural cavity. It often makes its way forwards, and points on the anterior abdominal wall, and finally it may burst into the peritoneal or pericardial cavities. Abscesses of the liver frequently require opening, and this must be done by an incision in the abdominal wall, in the thoracic wall, or in the lumbar region, according to the direction in which the abscess is tracking. The incision through the abdominal wall is to be preferred when possible. The abdominal wall is incised over the swelling, and, unless the peritoneum is adherent, gauze is packed all round the exposed liver surface, the abscess opened, and a large drainage tube inserted.

Hydatid cysts are more often found in the liver than in any of the other viscera. The reason of this is not far to seek. The embryo of the egg of the *Tænia echinococcus*, being liberated in the stomach by the disintegration of its shell, bores its way through the gastric walls and usually enters a blood-vessel, and is carried by the blood-stream to the hepatic capillaries, where its onward course is arrested, and where it undergoes development into the fully formed hydatid.

Ptosis of the liver, or hepatoptosis, from abnormal laxity of its ligaments and failure of the support it usually receives from the subjacent viscera, is an occasional cause of various nervous and gastro-intestinal disturbances. It has been very fully described by Glénard and his pupils. In women who have used very tight corsets and in men who have worn tightly buckled belts, the lower margin of the right lobe may become elongated by the pressure, producing an abnormal lobe known as the *linguiform* or *Riedel's lobe*. This may cause indefinite abdominal symptoms suggesting dyspepsia or disease of the gall-bladder; and if discovered accidentally, a Riedel's lobe may be mistaken for a tumour of the right kidney, of the colon or pancreas, or even of the vermiform process.

The gall-bladder may become distended in cases of obstruction of its duct or of the common bile-duct, or from a collection of gall-stones in its interior, thus forming a large tumour. The swelling is pear-shaped, and projects downwards and forwards towards the umbilicus. It moves with respiration, since it is attached to the liver. To relieve this condition, the gall-bladder must be opened (*cholecystotomy*) and the gall-stones removed. The operation is performed by an incision, 5 cm. to 7 cm. long, through the lateral part of the right Rectus, commencing at the costal margin. The peritoneal cavity is opened, and the tumour having been found, gauze is packed round it to protect the peritoneal cavity, and it is aspirated. When the contained fluid has been evacuated the flaccid bladder is drawn out of the abdominal wound and its wall incised; any gall-stones in the bladder are now removed. If the case is one of obstruction of the duct, an attempt must be made to dislodge the stone by manipulation through the wall of the duct. If this does

not succeed, the safest plan is to incise the duct, extract the stone, and close the incision by fine sutures in two layers. The obstruction having been removed, the edges of the incision in the gall-bladder may be sutured round a drainage tube which is inserted into the cavity; this fistulous opening usually closes in the course of a few weeks. The gall-bladder may be completely removed if it be quite certain that no cause for biliary obstruction remain: this is also done for primary malignant growth of the viscus.

Obstruction of the common bile-duct apart from stone is often due to occlusion of this canal by pressure of malignant growths, especially those commencing in the pylorus or pancreas. It is also seen following ulceration of the duct, cicatricial contraction of the scar tissue taking place. Enormous distension, both of the common duct itself and of its radicles in the liver substance, may occur at times.

UROGENITAL APPARATUS

The urogenital apparatus consists of (a) the urinary organs for the secretion, and discharge of the urine, and (b) the genital organs, which are concerned with the process of reproduction.

THE URINARY ORGANS

The urinary organs comprise the *kidneys*, which secrete the urine; the *ureters*, which convey it to the *urinary bladder*; and the *urethra*, through which it is discharged from the bladder.

THE KIDNEYS (RENES)

The *kidneys* are situated in the posterior part of the abdomen, one on either side of the vertebral column, behind the peritoneum, and are surrounded by a mass of fat and loose areolar tissue. Their upper extremities are on a level with the upper border of the twelfth thoracic vertebra, their lower, with the third lumbar vertebra. The right kidney is usually slightly lower than the left, probably on account of the vicinity of the liver; the left is a little longer and narrower than the right. The long axis of each kidney is directed downwards and lateralwards; the transverse axis lateralwards and backwards.

Each kidney is about 11 cm. in length, 6 cm. in breadth, and about 3 cm. in thickness. The weight of the kidney in the adult male varies from 125 gm. to 170 gm., in the adult female from 115 gm. to 155 gm.

The kidney has a characteristic form, and presents for examination two surfaces, two borders, and an upper and a lower extremity.

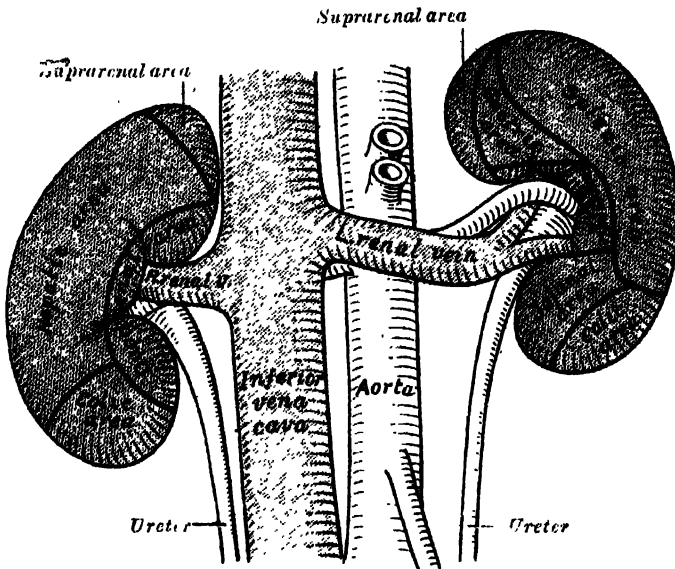
Relations.—The *anterior surface* (figs. 1042, 1057) of either kidney is convex, and looks forwards and lateralwards. Its relations to adjacent viscera differ on the two sides of the body.

(a) *Anterior surface of right kidney.*—A narrow portion at the upper extremity is in contact with the right suprarenal gland. A large area just below this and involving about three-fourths of the surface, lies in the renal impression on the inferior surface of the liver, and a narrow but somewhat variable area near the medial border is in contact with the descending part of the duodenum. The lower part of the anterior surface is in contact laterally with the right colic flexure, and medially, as a rule, with the small intestine. The area in relation with the small intestine and the greater part of the area in contact with the liver are covered by peritoneum; the suprarenal, duodenal, and colic areas are devoid of peritoneum.

(b) *Anterior surface of left kidney.*—A small area along the upper part of the medial border is in relation with the left suprarenal gland, and the upper two-thirds of the lateral half of the anterior surface are in contact with the renal impression on the spleen. A somewhat quadrilateral field, about the middle of the anterior surface, marks the site of contact with the body of the pancreas, on the deep surface of which are the lienal vessels. Above

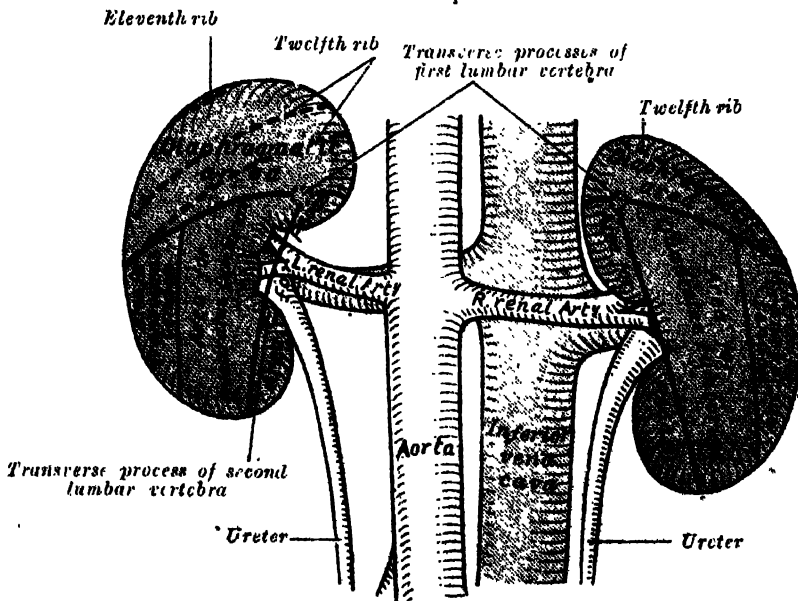
this is a small triangular portion, between the suprarenal and splenic areas, in contact with the stomach. Below the pancreatic area the lateral part is

FIG. 1057.—The anterior surfaces of the kidneys, showing the areas of contact of the neighbouring viscera.



in relation with the left colic flexure, the medial with the small intestine. The areas in contact with the stomach and spleen are covered by the peritoneum of the omental bursa, while that in relation to the small intestine is covered by the peritoneum of the main cavity; behind the latter are some branches of

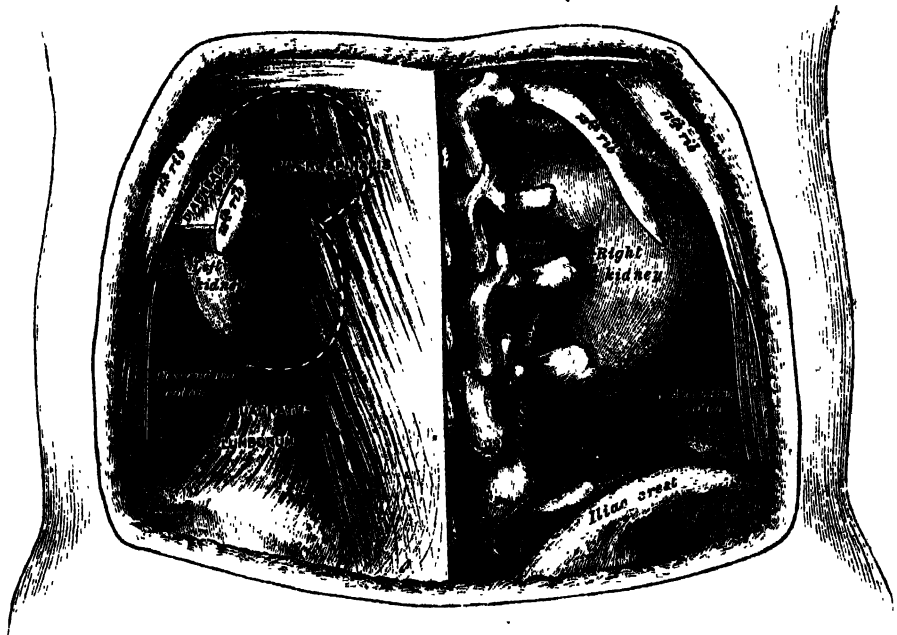
FIG. 1058.—The posterior surfaces of the kidneys, showing the areas of relation to the parietes.



the left colic vessels. The suprarenal, pancreatic, and colic areas are devoid of peritoneum.

The *posterior surface* (figs. 1058, 1059) of either kidney is directed backwards and medialwards. It is imbedded in areolar and fatty tissue, and is devoid of peritoneal covering. It lies upon the Diaphragm, the medial and lateral lumbocostal arches, the Psoas major, the Quadratus lumborum, and the tendon of origin of the Transversus abdominis, the subcostal, and one or two of the upper lumbar arteries, and the last thoracic, iliohypogastric, and ilio-inguinal nerves. The right kidney rests upon the twelfth rib, the left usually on the eleventh and twelfth. The Diaphragm separates the kidney from the pleura, which dips down to form the phrenicocostal sinus, but frequently the muscular fibres of the Diaphragm are defective or absent over a triangular area immediately above the lateral lumbocostal arch, and when this is the case the perinephric areolar tissue is in contact with the diaphragmatic pleura.

FIG. 1059.—The relations of the kidneys from behind.



The *superior extremity* is thick and rounded, and is nearer the median line than the lower; it is surmounted by the suprarenal gland, which covers also a small portion of the anterior surface.

The *inferior extremity*, smaller and thinner than the superior, extends to within 5 cm. of the iliac crest.

The *lateral border* is convex; that of the left kidney is in contact, at its upper part, with the spleen.

The *medial border* is concave in the centre, and convex towards either extremity; it is directed forwards and a little downwards. Its central part presents a deep vertical fissure, the *hilum*, which transmits the vessels, nerves and ureter, and is bounded by overhanging anterior and posterior lips. Above the hilum the medial border is in relation with the suprarenal gland.

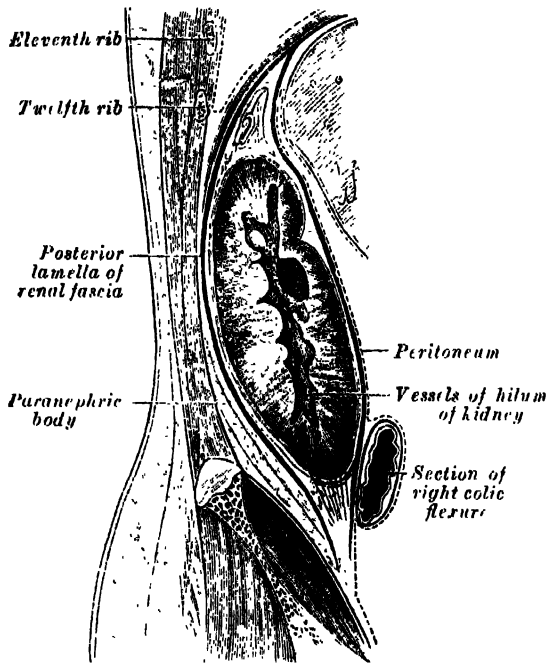
The relative positions of the main structures in the hilum are as follows: the renal vein is in front, the artery in the middle, and the ureter behind and directed downwards. Frequently, however, branches of both artery and vein are placed behind the ureter.

The hilum expands into a central cavity termed the *renal sinus*: this contains the renal calyces and the upper part of the renal pelvis, surrounded by some fat in which the branches of the renal vessels and nerves are imbedded.

The *renal calyces*, from seven to thirteen in number, are cup-shaped tubes, each of which embraces one or more of the renal papillæ (p. 1147); they unite

to form two or three short tubes, and these in turn join to form a funnel-shaped sac, termed the *renal pelvis*.

FIG. 1060.—A sagittal section through the posterior abdominal wall showing the relations of the capsule of the kidney. (After Gerota.)



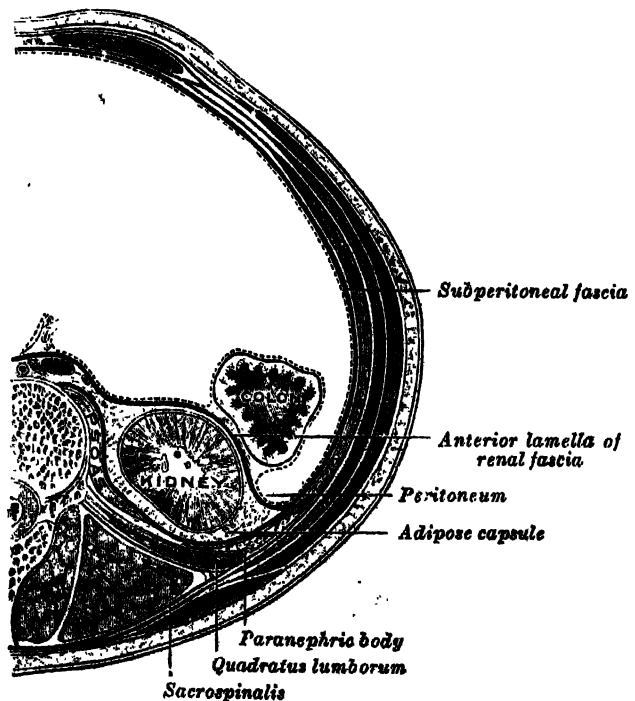
The renal pelvis, wide above and narrow below, is situated partly inside and partly outside the renal sinus, and is on a level with the spinous process of the first lumbar vertebra; at its neck or lower tapering end the ureter begins.

The kidney and its vessels are imbedded in a mass of fatty tissue, termed the *adipose capsule*, which is thickest at the borders of the kidney and is prolonged through the hilum into the renal sinus. The kidney and the adipose capsule are enclosed in a sheath of fibrous tissue continuous with the subperitoneal fascia, and named the *renal fascia* (figs. 1060, 1061). At the lateral border of the kidney the renal fascia splits into an anterior and a posterior layer. The anterior layer is carried medialwards in front of the kidney and its vessels,

and is continuous over the aorta with the corresponding layer of the opposite

side. The posterior layer extends medialwards behind the kidney and blends with the fascia on the *Quadratus lumborum* and *Psoas major*, and through this fascia is attached to the vertebral column. Above the suprarenal gland the two layers of the renal fascia fuse, and unite with the fascia of the Diaphragm; below they remain separate, and are gradually lost in the subperitoneal fascia of the iliac fossa. The renal fascia is connected to the fibrous tunic of the kidney by numerous trabeculae, which traverse the adipose capsule, and are strongest near the lower end of the organ. Behind the renal fascia is a

FIG. 1061.—A transverse section, showing the relations of the capsule of the kidney. (After Gerota.)



considerable quantity of fat, which constitutes the *paranephric body*. The kidney is held in position partly through the attachments of the renal fascia and partly by the apposition of the neighbouring viscera.

General structure of the kidney.—In the fetus the kidney consists of about twelve distinct lobules, but in the adult these are completely fused so that the organ presents a uniformly smooth surface. It is invested by a fibrous capsule which is easily stripped off; beneath the fibrous capsule is an incomplete layer of smooth muscle-fibres. The kidney is dense in texture, but is easily lacerable by mechanical force. If a vertical section be made from its convex to its concave border, and the loose tissue and fat removed from around the vessels and the excretory duct, the renal sinus will be seen surrounded at all parts but one by the proper kidney-substance (fig. 1062). The fibrous capsule is prolonged into the sinus round the lips of the hilum, to become continuous with the outer coat of the renal pelvis.

The kidney is composed of an internal *medullary* and an external *cortical* substance.

The *medullary substance* consists of a series of pale striated conical masses, termed the *renal pyramids*, the bases of which are directed towards the circumference of the kidney, while their apices converge towards the renal sinus, where they form prominent papillæ projecting into the interior of the calyces, each calyx receiving from one to three papillæ.

The *cortical substance* is reddish-brown in colour, and soft and granular in consistence. It lies immediately beneath the fibrous tunic, arches over the bases of the pyramids, and dips in between adjacent pyramids towards the renal sinus. The parts dipping in between the pyramids are named the *renal columns* (Bertini), while the portions which connect the renal columns with each other and intervene between the bases of the pyramids and the fibrous tunic are called the *cortical arches* (indicated between A and A' in fig. 1062). If the cortex be examined with a lens, it will be seen to consist of a series of lighter-coloured, conical areas, termed *medullary rays*, and a darker-coloured intervening substance, which from the complexity of its structure is named the convoluted part. The rays gradually taper towards the circumference of the kidney, and consist of a series of outward prolongations from the base of each renal pyramid.

The cortical and medullary substances are made up of renal tubules and blood-vessels, united and bound together by a connecting stroma.

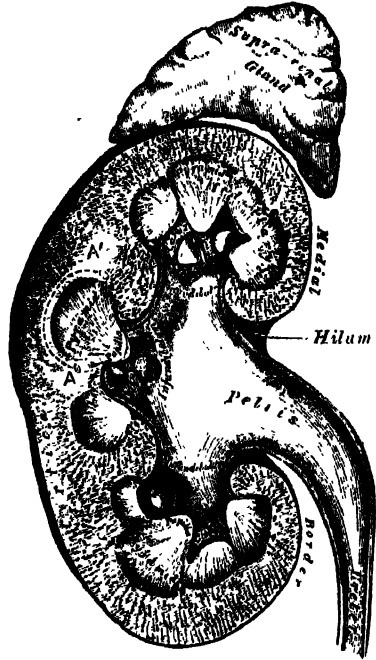
Minute Anatomy.—The renal tubules (fig. 1063) commence in the cortical substance, and after pursuing a very tortuous course through the cortical and medullary substances finally end at the apices of the renal pyramids by open mouths. If the surface of one of the papillæ be examined with a lens, it will be seen to be studded over with minute openings, the orifices of the renal tubules, from sixteen to twenty in number, and if pressure be made on a fresh kidney, urine will be seen to exude from these orifices. The tubules commence in the convoluted part and renal columns as the *Malpighian bodies*, which are small rounded masses of a deep red colour, averaging about 0.2 mm. in diameter. Each of these bodies is composed of two parts: a central *glomerulus* of vessels, and a membranous envelope, the *capsule of Bowman*, which is the small pouch-like commencement of a renal tubule.

The *glomerulus* is a lobulated tuft of convoluted capillary blood-vessels, held together by scanty connective tissue. This capillary network is derived from a small arterial twig, the *afferent vessel*, which enters the capsule, generally at a point opposite to that at which the latter is connected with the tubule; the *efferent vessel* emerges from the capsule at the same point. The afferent vessel is usually the larger of the two (figs. 1064, 1065).

Bowman's capsule is the blind expanded end of the renal tubule, indented for the reception of the glomerulus. It consists of a basement membrane, lined by a single layer of flattened epithelial cells. Thus between the glomerulus and the outer layer of the capsule there is a space lined by a continuous layer of squamous cells; this cavity varies in size according to the state of secretion and the amount of fluid present in it. In the fetus and young subject the lining epithelial cells are polyhedral or even columnar.

Each renal tubule consists of the following parts: (1) *Bowman's capsule*, already described, (2) a constricted portion, the *neck*, (3) the *first convoluted tubule*, (4) the *spiral*

FIG. 1062.—A vertical section of kidney.



tubule, which takes a course towards the medulla, (5) the descending limb of Henle's loop, narrower than the preceding, and running into the medullary substance, where it turns to form (6) the loop of Henle, (7) the ascending limb of Henle's loop, broader than the descending limb, which re-enters the cortical substance, (8) an irregular, angular

FIG. 1063.—A scheme of a renal tubule and its vascular supply.

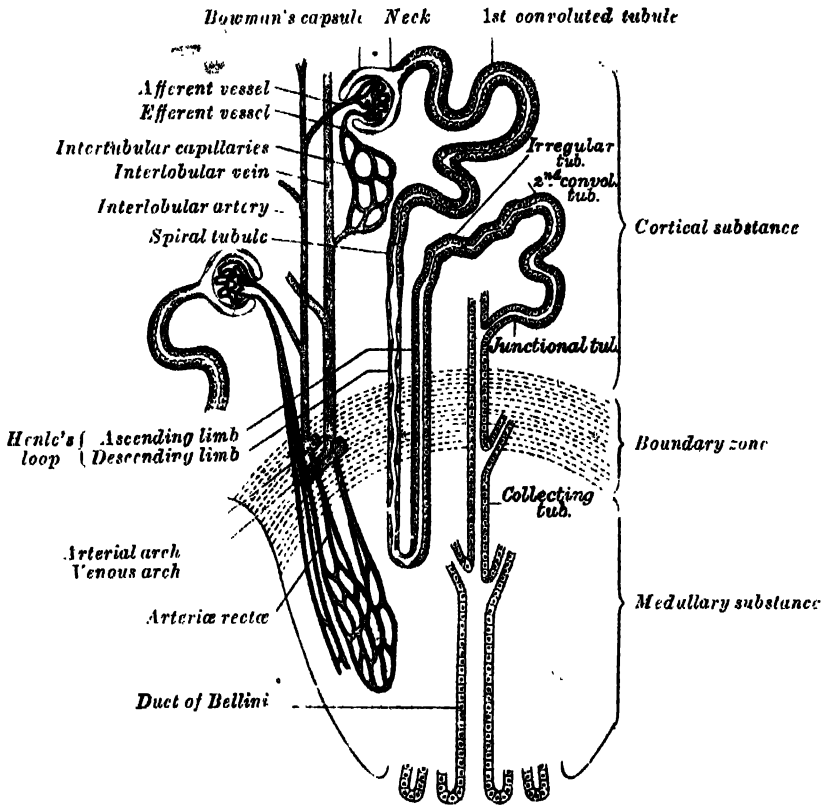


FIG. 1064.—The distribution of the blood-vessels in the cortex of kidney.

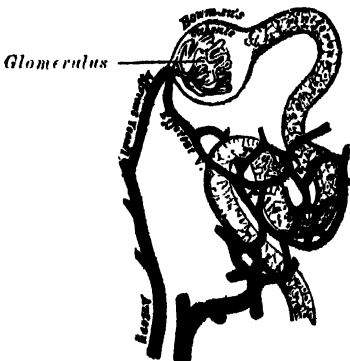
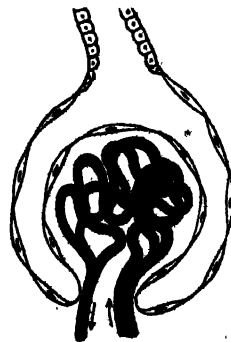


FIG. 1065.—A glomerulus.



segment, the zig-zag tubule, (9) the second convoluted tubule, (10) the junctional tubule, which opens into (11) the collecting tubule (fig. 1063).

The straight or collecting tubules commence in the medullary rays of the cortex; they unite at short intervals with one another, the terminal tubes presenting a considerable increase in calibre, and are known as the ducts of Bellini; they finally open on the summit of one of the papillae.

Structure of the renal tubules.—The renal tubules consist of a basement membrane lined by epithelium. In the neck the epithelium is continuous with that lining Bowman's capsule, and like it consists of flattened cells each containing an oval nucleus (fig. 1067). The two convoluted tubules, the spiral and zigzag tubules, and the ascending limb of Henle's loop are lined by a type of epithelium which is histologically similar in all. The cells are somewhat columnar in shape and dovetail into one another on their lateral aspects. Each has a striated border next the lumen of the tube; its substance is granular, the granules in the outer portion being arranged in vertical rows. The nucleus is spherical and situated about the centre of the cell. In the descending limb of Henle's loop the epithelium resembles that found in the Malpighian capsule and the commencement of the tube, consisting of flat, clear epithelial plates, each with an oval nucleus (fig. 1066). The nuclei alternate on opposite surfaces of the tubule so that the lumen remains fairly constant.

In the straight tubule the epithelium is clear and cubical: in its papillary portion the cells are columnar and transparent (fig. 1068).

The renal blood-vessels.—Before entering the kidney, each artery divides into four or five branches which at the hilum lie mainly between the renal vein and ureter, the vein being in front, the ureter behind; one branch usually lies behind the ureter. Each vessel gives off some small branches to the suprarenal glands, to the ureter, and to the surrounding cellular tissue and muscles.

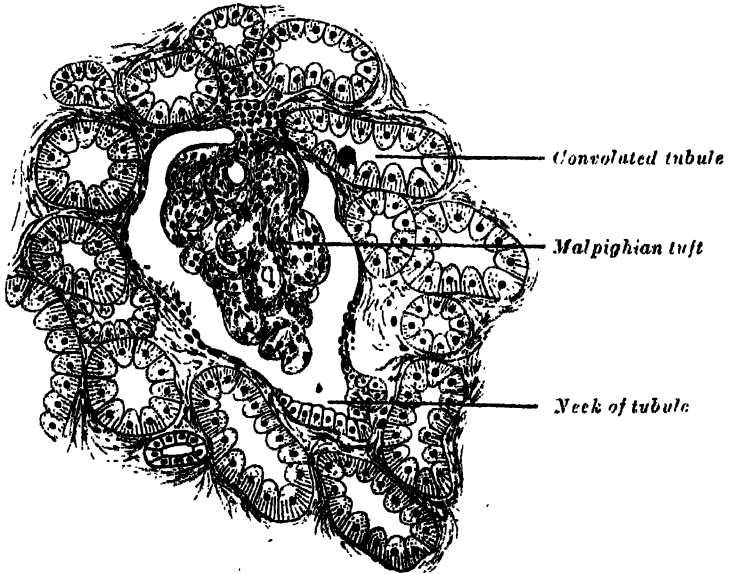
Frequently a second renal artery, termed the *inferior renal*, is given off from the abdominal aorta at a lower level, and supplies the lower portion of the kidney, whilst occasionally an additional artery enters the upper part of the kidney. The branches of the renal artery, while in the sinus, give off a few twigs for the nutrition of the surrounding tissues, and end in the *arterie propriae renales*, which enter the kidney proper in the

FIG. 1066.—A longitudinal section of the descending limb of Henle's loop.



a. Membrana propria. b. Epithelium.

FIG. 1067.—A section of the cortex of a human kidney ×250.



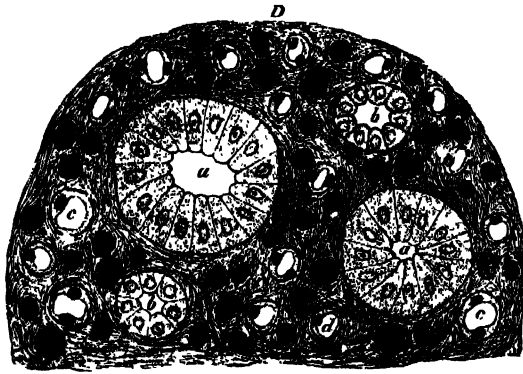
renal columns. Two of these pass to each renal pyramid, and run along its sides for its entire length, giving off in their course the afferent vessels of the Malpighian bodies in the renal columns. Having arrived at the bases of the pyramids, they form arterial arches or arcades which lie in the boundary zone between the bases of the pyramids and the cortical arches, the convexity of the vessels being towards the surface of the kidney.

Interlobular arteries (fig. 1063) are given off from the convex side of the arterial arcade, and pass directly outwards between the medullary rays to reach the fibrous tunic, where they end in the capillary network of this part. These vessels do not anastomose with each other, but form what are called *end-arteries*. In their outward course they give off the *afferent vessels* for the glomeruli (p. 1147). From each glomerulus the corresponding *efferent vessel* arises, and breaks up into a number of branches which form a dense *plexus* around the adjacent renal tubules.

A *second set of branches* from the arterial arcades supply the renal pyramids, which they enter at their bases; and, passing straight through their substance to their apices, terminate in the *plexuses* found in that situation. They are called the *arteriæ rectæ*. The efferent vessels from the glomeruli nearest the medulla break up into leashes of straight vessels (*false arteriæ rectæ*) which pass down into the medulla and join the plexus of vessels there (fig. 1063).

The *renal veins* arise from three sources, viz. the veins beneath the fibrous tunic, the plexuses around the convoluted tubules in the cortex, and the plexuses situated at the apices of the renal pyramids. The veins beneath the fibrous tunic (*venæ stellatæ*) are stellate in arrangement, and are derived from the capillary network into which the terminal branches of the interlobular arteries break up. These form the commencement

Fig. 1068.- A transverse section of the pyramidal substance of the kidney of a pig, the blood-vessels of which were injected.



a. Large collecting tube, cut across, lined with cylindrical epithelium. b. Branch of collecting tube, cut across, lined with cubical epithelium. c, d. Henle's loops cut across. e. Blood-vessels cut across.

of the *interlobular veins*, which pass inwards between the rays, receive branches from the plexuses around the convoluted tubules, and, having arrived at the bases of the pyramids, join the convex sides of the venous arches.

The *venæ rectæ* arise from the plexuses at the apices of the medullary pyramids. They run outwards in a straight course between the tubes of the medullary substance, and join the concave sides of the venous arcades; these in turn unite and form veins which pass along the sides of the pyramids (fig. 1063).

The latter vessels, *venæ propriae renales*, accompany the arteries of the same name, and quit the kidney substance to enter the sinus. In this cavity they join the corresponding veins from the other pyramids to form the *renal vein*, which emerges from the kidney at the hilum and opens into the inferior vena cava; the left vein is longer than the right, and crosses in front of the abdominal aorta.

Nerves of the kidney.—The *nervus* of the kidney, although small, are about fifteen in number. They have small ganglia developed upon them, and are derived from the renal plexus, which is formed by branches from the coeliac plexus, the lower and outer part of the coeliac ganglion and aortic plexus, and from the lesser and lowest splanchnic nerves. The *spinal nerves* which supply the kidney are derived from the tenth, eleventh, and twelfth thoracic segments of the medulla spinalis. The nerves communicate with the testicular plexus, a circumstance which may explain the occurrence of pain in the testis in affections of the kidney. They accompany the renal artery and its branches, and are distributed to the blood-vessels and to the cells of the urinary tubules.

The *lymphatics* of the kidney are described on p. 782.

Connective tissue, or intertubular stroma.—Although the tubules and vessels are closely packed, a small amount of connective tissue, continuous with the fibrous tunic, binds them firmly together and supports the blood-vessels, lymphatics, and nerves.

Applied Anatomy.—Malformations of the kidney are not uncommon. There may be an entire absence of one kidney, but, according to Morris, the number of these cases is

'excessively small': or there may be congenital atrophy of one kidney, when the kidney is very small, but usually healthy in structure. These cases are of great importance, and must be duly taken into account when nephrectomy is contemplated. A more common malformation is where the two kidneys are fused together. They may be joined together only at their lower ends by means of a thick mass of renal tissue, so as to form a horseshoe-shaped body, or they may be completely united, forming a disc-like kidney, from which two ureters descend into the bladder. These fused kidneys are generally situated in the middle line of the abdomen, but may be misplaced as well. In some mammals (e.g. ox and bear) the kidney consists of a number of distinct lobules; this lobulated condition is characteristic of the kidney of the human foetus, and traces of it may persist in the adult. Sometimes the pelvis is duplicated, while a double ureter is not very uncommon.

One or both kidneys may be misplaced as a congenital condition, and remain fixed in this abnormal position. They are then very often misshapen. They may be situated higher, though this is very uncommon, or lower than normal, or removed farther from the vertebral column than usual; or they may be displaced into the iliac fossa, over the sacro-iliac joint, on to the promontory of the sacrum, or into the pelvis between the rectum and bladder or by the side of the uterus. In these latter cases they may give rise to very serious trouble. The kidney may also be misplaced as a congenital condition, but may not be fixed; it is then known as a *floating kidney*. It is believed to be due to the fact that the kidney is completely enveloped by peritoneum, which passes backwards to the vertebral column as a double layer, forming a mesonephron which permits of movement taking place. The kidney may also be misplaced as an acquired condition; in these cases the kidney is mobile in the tissues by which it is surrounded, moving in the perinephric tissues. This condition is known as *movable kidney*, and is more common in the female than in the male. It occurs in badly nourished people, or in those who have become emaciated from any cause. It must not be confounded with the *floating kidney*, which is a congenital condition due to the development of a mesonephron.

Injuries of the kidney are generally due to some severe crushing force, as from being run over by a heavy waggon or cart, or from the abdomen being compressed between the buffers of two railway carriages. When a laceration occurs on the posterior surface of the organ, infiltration of blood and urine takes place into the retroperitoneal connective tissue; this is often followed by suppuration, and death may ensue from septic poisoning. When the laceration is in front, the peritoneum may be torn and extravasation of blood and urine may take place into the peritoneal cavity. Death may occur from hæmorrhage or peritonitis. Occasionally, when rupture involves the pelvis of the kidney or the commencement of the ureter, this duct may become blocked, and hydronephrosis follow. Sometimes the kidney may be bruised by blows in the loin, or by being compressed between the lower ribs and the ilium when the body is violently bent forwards. This is followed by a little transient hæmaturia, which, however, speedily passes off.

The loose cellular tissue around the kidney may be the seat of suppuration, constituting *perinephric abscess*. This may be due to injury, or to disease of the kidney itself, or to extension of inflammation from neighbouring parts. The abscess tends to point externally in the groin or loin.

Tumours of the kidney may be recognised by their position: by the resonant colon lying in front of them; and by their rounded outline not presenting a notched anterior margin like the spleen, with which they are most likely to be confounded. The *hypernephroma*, a tumour arising from suprarenal 'rests' or inclusions in the cortex or medulla of the kidney, is not infrequent. When occurring in children it is often associated with precocious growth of the body generally and of the hair and sexual organs in particular. Arising, as it often does, in the kidney, a hypernephroma is indistinguishable from a true renal tumour so far as the physical signs and symptoms go; it is really, however, a tumour of the suprarenal gland substance.

The examination of the kidney should be bimanual; that is to say, one hand should be placed in the flank and firm pressure made forwards, while the other hand is buried in the abdominal wall, over the situation of the organ. Manipulation of the kidney frequently produces a peculiar sickening sensation, sometimes with faintness.

The kidney may require exposure for exploration or the evacuation of pus (*nephrotomy*); it may be incised for the removal of stone (*nephrolithotomy*); it may be sutured when movable or floating (*nephropexy*); or it may be removed (*nephrectomy*). It may be exposed either by a lumbar or an abdominal incision; except in cases of very large tumours, a lumbar incision is best, as it has the advantages of not opening the peritoneum, and of affording admirable drainage. An oblique incision should be made, starting at the lateral border of the Sacrospinalis, 1 cm. below the last rib and directed downwards and forwards towards a point 2.5 cm. in front of the anterior superior spine of the ilium. The structures divided are the skin, the superficial fascia with the cutaneous nerves, the deep fascia, the posterior border of the Obliquus externus abdominis, and the outer border of the Latissimus dorsi; the Obliquus internus and the posterior aponeurosis of the Transversus abdominis; the lateral border of the Quadratus lumborum; the deep layer of the lumbodorsal fascia and the transversalis fascia. The fatty tissue around the kidney is now exposed to view, and must be separated by the fingers, or a director, in order to reach the kidney. The operations of nephrolithotomy, for the removal of calculi from the kidney, and nephrotomy, or incision of the kidney for abscess, &c., are generally

performed by the lumbar incision, especially if the organ contains pus. The abdominal operation is best performed by an incision in the lateral part of the Rectus abdominis on the side of the kidney to be removed.

This route is also generally chosen for nephrectomy. The abdominal operation is best performed by an incision in the lateral part of the Rectus abdominis on the side of the kidney to be removed. The incision is then reached from the lateral side of the colon, ascending or descending, as the case may be, and thus the vessels of the colon are not interfered with. The incision commencing just below the costal arch is made of varying length, according to the size of the kidney. The abdominal cavity having been opened, the intestines are drawn medialwards and the peritoneum covering the kidney to the lateral side of the colon is incised, so that the fingers can be introduced behind the peritoneum. The kidney must now be enucleated, and the vessels firmly ligatured and divided, the ureter being tied separately. The particular advantage of the abdominal operation is that the condition of the other kidney can be ascertained by manual examination, before the removal of the diseased kidney is finally decided upon; and, further, involvement of neighbouring structures by a new growth, rendering removal impossible, can only be discovered by the abdominal route.

Nephropexy is the name given to the operation for fixing a movable kidney. The kidney is reached by the lumbar incision, and is freely separated from its perinephric capsule. Sutures are then passed through the true capsule of the organ and are brought out above the upper end of the wound. When these sutures are tied, the kidney is tightly anchored in position; at the same time a flap of the true capsule can be separated from the parenchyma of the kidney and passed around the last rib and sutured down again, so as to form a sling for the kidney from the rib.

THE URETERS

The **ureters** are the two tubes which convey the urine from the kidneys to the urinary bladder. Each measures from 25 cm. to 30 cm. in length, and is a thick-walled, narrow, cylindrical tube which is directly continuous, near the lower end of the kidney, with the tapering extremity of the renal pelvis. It runs downwards and medialwards in front of the Psoas major and, entering the pelvic cavity, finally opens into the fundus of the urinary bladder.

The *abdominal part* lies behind the peritoneum on the medial part of the Psoas major, and is crossed obliquely by the testicular vessels. It enters the pelvic cavity by crossing either the termination of the common, or the commencement of the external, iliac vessels.

At its origin the *right* ureter is usually covered by the descending part of the duodenum; in its course downwards it lies to the right of the inferior vena cava, and is crossed by the right colic and ileocolic vessels, while near the superior aperture of the pelvis it passes behind the lower part of the mesentery and the terminal part of the ileum. The *left* ureter is crossed by the left colic vessels, and near the superior aperture of the pelvis passes behind the sigmoid colon and its mesentery.

The *pelvic part* runs at first downwards on the lateral wall of the pelvic cavity, along the anterior border of the greater sciatic notch and under cover of the peritoneum. It lies in front of the hypogastric artery, and medially to the obturator nerve and the umbilical, obturator, inferior vesical, and middle hæmorrhoidal arteries. Opposite the lower part of the greater sciatic foramen it inclines medialwards, and reaches the lateral angle of the urinary bladder, where it is situated in front of the upper end of the seminal vesicle (and at a distance of about 5 cm. from the opposite ureter); here the ductus deferens crosses to its medial side, and the vesical veins surround it. Finally, the ureters run obliquely for about 2 cm. through the wall of the bladder and open by slit-like apertures into the cavity of that viscus at the lateral angles of the trigone. When the bladder is distended the openings of the ureters may be about 5 cm. apart, but when it is empty and contracted the distance between them is diminished by one-half. Owing to their oblique course through the coats of the bladder, the upper and lower walls of the terminal portions of the ureters become closely applied to each other when the bladder is distended, and, acting as valves, prevent regurgitation of urine.

In the *female*, the ureter forms, as it lies in relation to the wall of the pelvis, the posterior boundary of a shallow depression named the *ovarian fossa*, in which the ovary is situated. It then runs medialwards and forwards on the lateral aspect of the cervix uteri and upper part of the vagina to reach the fundus of the bladder. In this part of its course it is accompanied for about 2.5 cm. by the uterine artery, which then crosses in front of the ureter.

and ascends between the two layers of the broad ligament. The ureter is distant about 2 cm. from the side of the cervix of the uterus.

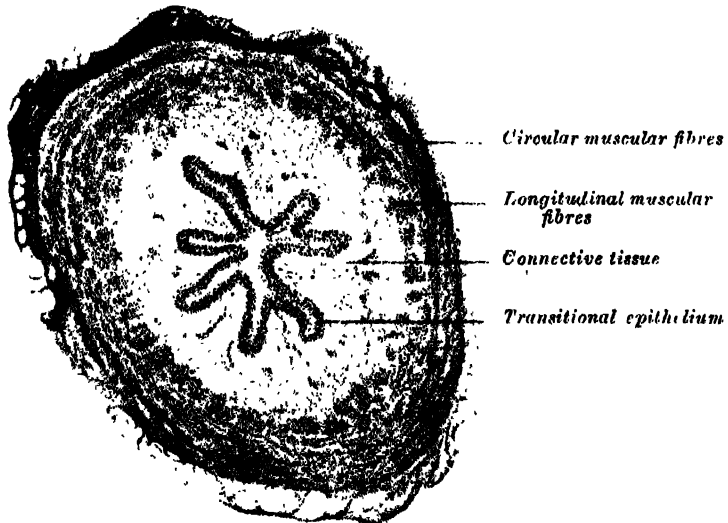
The ureter is sometimes duplicated on one or both sides, and the two tubes may remain distinct as far as the fundus of the bladder; they rarely open separately into the bladder cavity.

Structure (fig. 1069).—The ureter is composed of three coats: fibrous, muscular, and mucous.

The *fibrous coat* is continuous at one end with the fibrous tunic of the kidney on the floor of the renal sinus; while at the other it is lost in the fibrous structure of the bladder.

In the renal pelvis the *muscular coat* consists of two layers, longitudinal and circular: the longitudinal fibres become lost upon the sides of the papillæ at the extremities of the calyces; the circular fibres surround the medullary substance in the same situation. In the ureter proper the muscular fibres are very distinct, and are arranged in three layers: an external longitudinal, a middle circular, and an internal, less distinct than the other two, but having a general longitudinal direction.

FIG. 1069.—A transverse section through the ureter of a sheep. Stained with hæmatoxylin and eosin. $\times 25$.



The *mucous coat* is smooth, and presents a few longitudinal folds which become effaced by distension. It is continuous with the mucous membrane of the bladder below, while it is prolonged over the papillæ of the kidney above. It consists of fibrous tissue containing many elastic fibres, and covered by transitional epithelium. The continuation of the epithelium over the renal papillæ is columnar in type.

The *arteries* supplying the ureter are branches from the renal, testicular or ovarian, hypogastric, and inferior vesical arteries.

The *nerves* are derived from the inferior mesenteric, spermatic, and pelvic plexuses; through these plexuses fibres are derived from the lower three thoracic and first lumbar segments of the medulla spinalis. Small ganglia and isolated ganglion-cells are found in the fibrous and muscular coats.

Applied Anatomy.—Rupture of the ureter is not a common accident, but occasionally occurs. If it be torn completely across, the urine collects in the retroperitoneal tissues; if it be not completely divided, the lumen of the tube may become strictured, and hydro-nephrosis or pyonephrosis result. The ureter may be accidentally wounded in some pelvic operations, such as removal of the uterus; if this should happen the divided ends must be sutured together, or failing to accomplish this an attempt may be made to implant the upper end into the bladder or rectum. If this cannot be carried out the only alternative is to remove the kidney immediately.

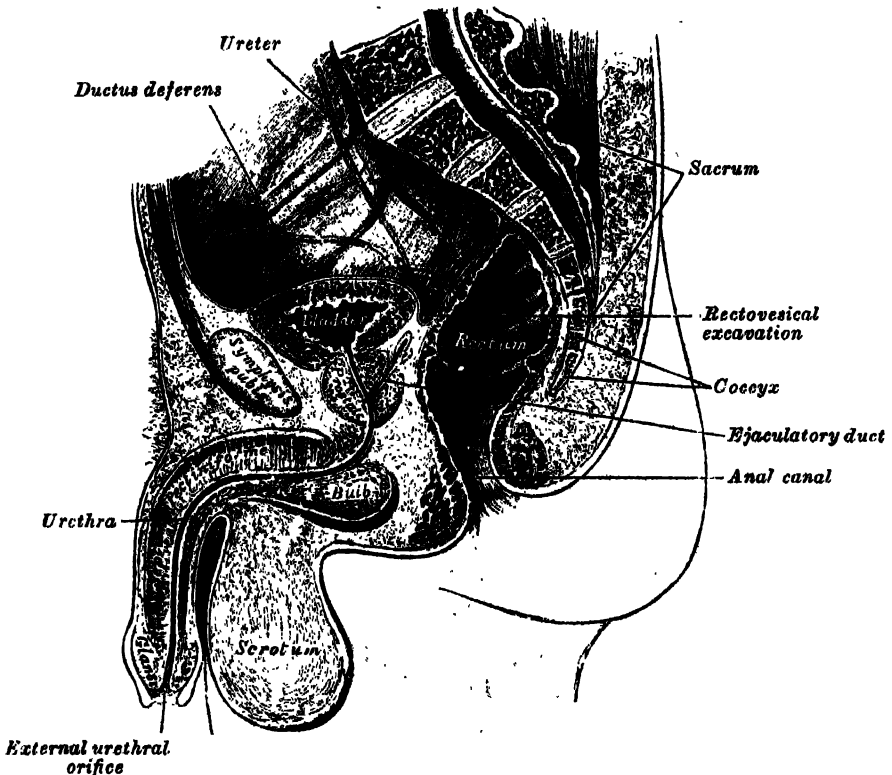
Stones not uncommonly become impacted in the ureter. These may occur at any part, but most commonly either at the point where the tube is crossing the pelvic brim or at the termination, where it is passing obliquely through the muscular wall of the bladder. In the former case, an incision with its centre opposite, and 2.5 cm. medially to, the anterior superior iliac spine dividing all the structures down to the peritoneum, enables

the operator to reach the ureter by pushing the unopened peritoneum inwards; the stone can then be felt in the ureter, the wall of which is incised, and the stone extracted, free drainage being provided for the escaping urine. When the stone is impacted at the vesical end of the tube a preliminary incision into the bladder is required, and by scratching through the mucous membrane overlying it the calculus can be removed.

THE URINARY BLADDER (VESICA URINARIA)

The urinary bladder (fig. 1070) is a sac which acts as a reservoir for the urine; its size and position vary with the amount of fluid it contains, and also with the state of distension of the neighbouring viscera.

FIG. 1070.—A median sagittal section through the male pelvis.



When the empty bladder is firmly contracted it has the form of a flattened tetrahedron. It has a fundus, a vertex, a superior and an inferior surface. The *fundus* (fig. 1071) is triangular in shape, and is directed downwards and backwards towards the rectum, from which it is separated by the rectovesical fascia, the vesiculæ seminales, and the terminal portions of the ductus deferentes. The *vertex* is directed forwards towards the upper part of the symphysis pubis, and from it the middle umbilical ligament (urachus) is continued upwards on the back of the abdominal wall to the umbilicus; the peritoneum folded over this ligament forms the middle umbilical fold. The *superior surface* is triangular, covered by peritoneum, and is in relation with the sigmoid colon and some coils of the small intestine. It is bounded on either side by a lateral border which separates it from the inferior surface, and behind by a posterior border, represented by a line joining the two ureters, which intervenes between it and the fundus. The lateral borders run from the ureters to the vertex, and from these borders the peritoneum extends to the walls of the pelvis. On either side of the bladder is a peritoneal depression named the *parametral fossa* (fig. 1001). The *inferior surface* is directed downwards, and is uncovered

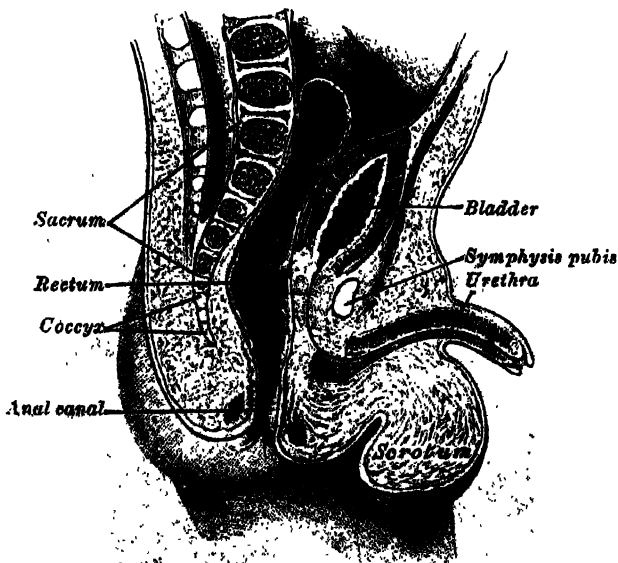
by peritoneum. It may be divided into a posterior or prostatic area and two inferolateral surfaces. The prostatic area, somewhat triangular, rests upon and

FIG. 1071.—The fundus of the urinary bladder, &c.



is in direct continuity with the base of the prostate; from it the urethra emerges. The inferolateral portions of the inferior surface are separated in front from the symphysis pubis by a mass of fatty tissue named the *retropubic pad*; behind,

FIG. 1072.—A sagittal section through the pelvis of a new-born male child.

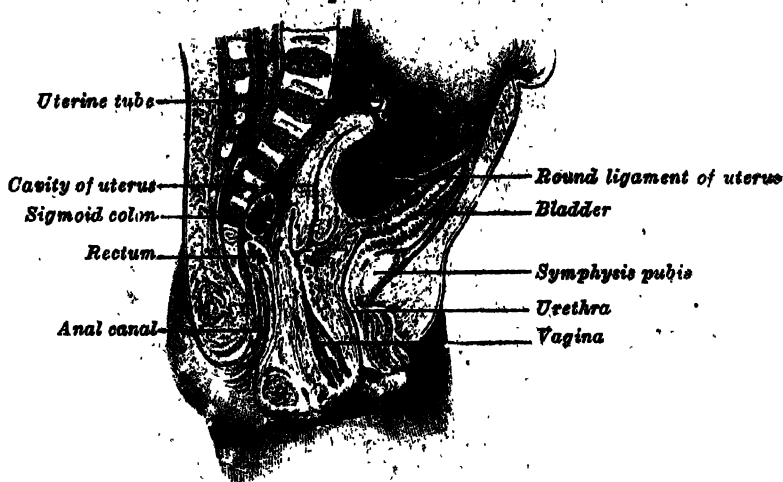


they are in contact with the fascia covering the Levatores ani and Obturatores interni.

When the bladder is empty it is placed entirely within the pelvis, the level of the obliterated hypogastric arteries, and below the portions of the ductus deferentes which are in contact with the of the pelvis.

As the bladder fills, its fundus, being more or less fixed, is only slightly depressed; while its superior surface gradually rises into the abdominal cavity, carrying with it its peritoneal covering, and at the same time rounding off the posterior and lateral borders. When the bladder is distended it assumes an ovoid form, the long diameter being directed upwards and forwards. In this condition it presents a posterosuperior, an antero-inferior, and two lateral surfaces, a fundus, and a summit. The posterosuperior surface is directed upwards and backwards, and is covered by peritoneum; behind, it is separated from the rectum by the rectovesical excavation, while its anterior part is in contact with the coils of the small intestine. The antero-inferior surface is devoid of peritoneum, and rests, below, against the pubic bones, above which it is in contact with the back of the anterior abdominal wall. The lower

FIG. 1078.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine separated the uterus from the bladder.



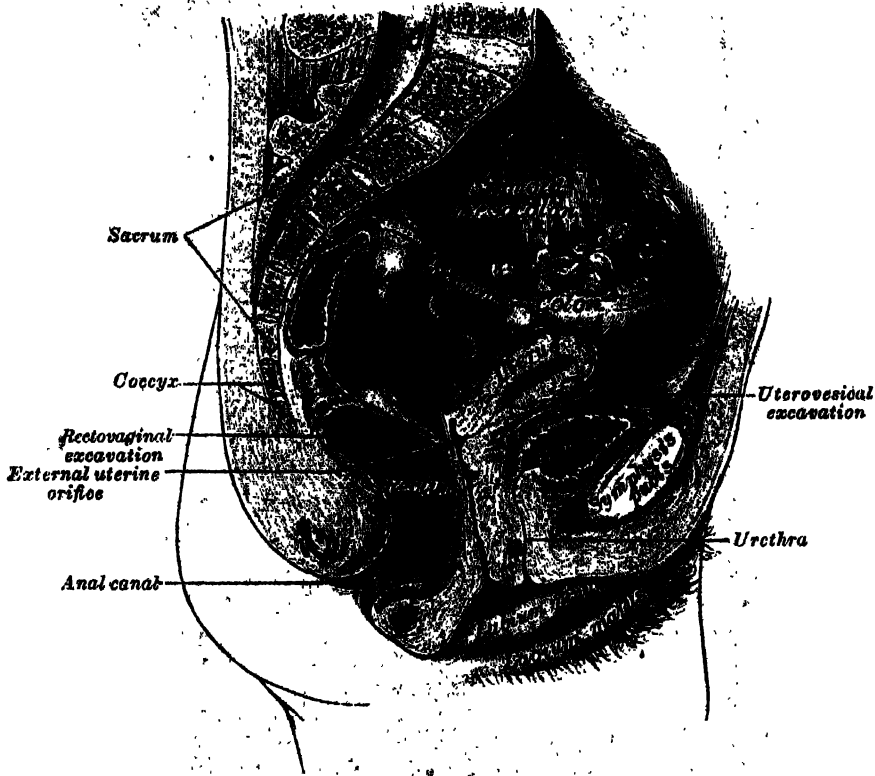
parts of the lateral surfaces are destitute of peritoneum, and are in contact with the lateral walls of the pelvis. The line of peritoneal reflection from the lateral surface is raised to the level of the obliterated hypogastric artery. The fundus undergoes little alteration in position, being only slightly lowered. It exhibits, however, a narrow triangular area, which is separated from the rectum merely by the rectovesical fascia. This area is bounded below by the prostate, above by the rectovesical fold of peritoneum, and laterally by the ductus deferentes. The ductus deferentes frequently come in contact with each other above the prostate, and under such circumstances the lower part of the triangular area is obliterated. The line of reflection of the peritoneum from the rectum to the bladder appears to undergo little or no change when the latter is distended; it is situated about 10 cm. from the anus. The summit of the bladder is directed upwards and forwards above the point of attachment of the middle umbilical ligament, and hence the peritoneum, which follows the ligament, forms a pouch of varying depth between the summit and the anterior abdominal wall.

In the new-born child (figs. 1072, 1073) the internal urethral orifice is at the level of the upper border of the symphysis pubis; the bladder therefore lies relatively at a much higher level in the infant than in the adult. Its anterior surface is in contact with about the lower two-thirds of that part of the abdominal wall which lies between the symphysis pubis and the umbilicus (Symington *). Its fundus is clothed with peritoneum as far as the level of the

internal orifice of the urethra. Although the bladder of the infant is usually described as an abdominal organ, Symington has pointed out that only about one-half of it lies above the plane of the superior aperture of the pelvis. Dine maintains that the internal urethral orifice sinks rapidly during the first three years, and then more slowly until the ninth year, after which it remains stationary until puberty, when it again slowly descends and reaches its adult position.

In the female, the bladder is in relation behind with the uterus and the upper part of the vagina (fig. 1074). It is separated from the anterior surface of the body of the uterus by the vesico-uterine excavation, but below the

FIG. 1074.—A median sagittal section through a female pelvis.



level of this excavation it is connected to the front of the cervix uteri and the upper part of the anterior wall of the vagina by areolar tissue. When the bladder is empty the uterus rests upon its superior surface.

Ligaments.—The bladder is connected to the pelvic wall by the fascia endopelvis. In front this fascial attachment is strengthened by a few muscular fibres, the *Pubicocystales*, which extend from the back of the pubic bones to the front of the bladder; behind other muscular fibres run from the fundus of the bladder to the sides of the rectum, in the sacrogenital folds, and constitute the *Rectovesicales*.

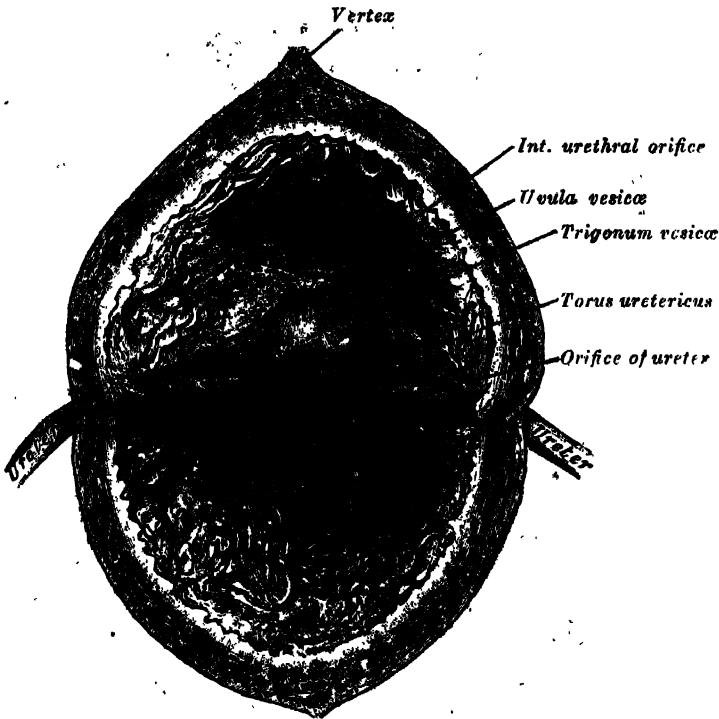
The vertex of the bladder is joined to the umbilicus by the remains of the umbilus which forms the *middle umbilical ligament*, a fibromuscular cord broad at its attachment to the bladder but narrowing as it ascends.

From the superior surface of the bladder the peritoneum is carried off in a series of folds which are sometimes termed the *false ligaments of the bladder*. Anteriorly there are three folds, the *middle umbilical fold* on the middle umbilical ligament, and two *lateral vesical folds* on the obliterated hypogastric arteries. The reflections of the peritoneum on to the side walls of the pelvis

form the lateral false ligaments, while the rectovesical or sacrogenital folds (p. 1089) constitute the posterior false ligaments.

Interior of the bladder (fig. 1075).—The mucous membrane lining the bladder is, over the greater part of the viscus, loosely attached to the muscular coat, and appears wrinkled or folded when the bladder is contracted; the folds are effaced when the bladder is distended. Over a small triangular area, termed the *trigonum vesicæ*, immediately above and behind the internal orifice of the urethra, the mucous membrane is firmly bound to the muscular coat, and is always smooth. The anterior angle of the trigonum vesicæ is formed by the internal orifice of the urethra; its posterolateral angles by the orifices of the ureters. Stretching between the latter openings is a slightly curved ridge, the *torus uretericus*, forming the base of the trigone and produced

FIG. 1075.—The interior of the bladder.



by an underlying bundle of non-striped muscular fibres. The lateral parts of this ridge extend beyond the openings of the ureters, and are named the *plicæ uretericæ*; they are produced by the terminal portions of the ureters as they traverse obliquely the bladder wall. When the bladder is illuminated the torus uretericus appears as a pale band and forms an important guide during the operation of introducing a catheter into the ureter.

The *orifices of the ureters* are placed at the posterolateral angles of the trigonum vesicæ, and are usually slit-like in form. In the contracted bladder they are about 2.5 cm. apart and about the same distance from the internal urethral orifice; in the distended viscus these measurements may be increased to about 5 cm.

The *internal urethral orifice* is placed at the apex of the trigonum vesicæ, in the most dependent part of the bladder, and is usually somewhat crescentic in form; the mucous membrane immediately behind it exhibits a slight elevation, the *uvula vesicæ*, caused by the middle lobe of the prostate.

Structure (fig. 1076).—The bladder is composed of four coats: serous, muscular, sub-mucous, and mucous.

This *serous coat* is a partial one, and is derived from the peritoneum. It invests the

superior surface and the upper parts of the lateral surfaces, and is reflected from these on to the abdominal and pelvic walls.

The *muscular coat* consists of three layers of unstriated muscular fibres: an external and an internal of longitudinal fibres, and a middle of circular fibres.

The *fibres of the external longitudinal layer* arise from the posterior surface of the body of the os pubis in both sexes (*musculi pubovesicales*), and in the male from the adjacent part of the prostate and its capsule. They pass, in a more or less longitudinal manner, up the inferior surface of the bladder, over its vertex, and then descend along its fundus to become attached to the prostate in the male, and to the front of the vagina in the female. At the sides of the bladder the fibres are arranged obliquely and intersect one another. This layer has been named the *Detrusor urinae* muscle.

The *fibres of the middle circular layer* are very thinly and irregularly scattered on the body of the organ, and, although to some extent placed transversely to the long axis of the bladder, are for the most part arranged obliquely. Towards the lower part of the bladder, round the internal urethral orifice, they are disposed in a thick circular layer, forming the *Sphincter vesicae*, which is continuous with the muscular fibres of the prostate.

The *internal longitudinal layer* is thin, and its fasciculi have a reticular arrangement, but with a tendency to assume for the most part a longitudinal direction.

Two bands of oblique fibres, originating behind the orifices of the ureters, converge to the back part of the prostate, and are inserted by means of a fibrous process into the middle lobe of that organ. They are the *muscles of the ureters*, described by Sir C. Bell, who supposed that during the contraction of the bladder they serve to retain the oblique direction of the ureters, and so prevent the reflux of the urine into them.

The *submucous coat* consists of a layer of areolar tissue, connecting together the muscular and mucous coats, and intimately united with the latter.

The *mucous coat* is thin, smooth, and of a pale rose colour. It is continuous above with that of the ureters, and below with that of the urethra; the epithelium covering it is of the transitional variety. The loose texture of the submucous layer allows the mucous coat to be thrown into folds or *rugae* when the bladder is empty. Over the trigonum vesicae the mucous membrane is closely attached to the muscular coat, and is not thrown into folds, but is smooth and flat. There are no true glands in the mucous membrane of the bladder, though certain mucous follicles which exist, especially near the neck of the bladder, have been regarded as such.

Vessels and Nerves.—The principal *arteries* of supply to the bladder are the superior, middle, and inferior vesical, derived from the anterior trunk of the hypogastric artery. The obturator and inferior gluteal arteries also send small branches to it, and in the female additional branches are derived from the uterine and vaginal arteries.

The *veins* form a complicated plexus on the inferior surface and fundus near the prostate, and end in the hypogastric veins.

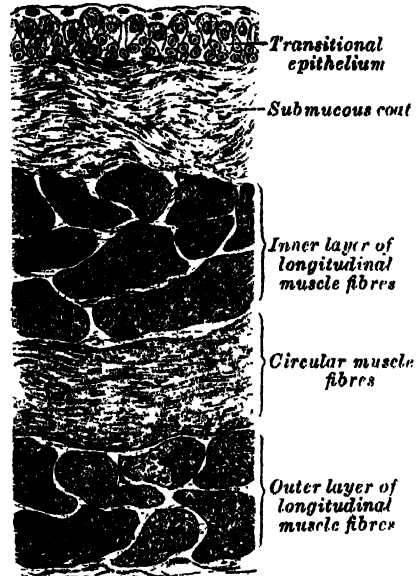
The *lymphatics* are described on p. 788.

The *nerves* of the bladder are (1) fine medullated fibres from the second, third, and fourth sacral nerves, and (2) non-medullated fibres from the hypogastric plexus. They are connected with ganglia in the outer and submucous coats, and are finally distributed, all as non-medullated fibres, to the muscular layer and epithelial lining of the viscus.

Applied Anatomy.—A defect of development, in which the bladder is implicated, is known under the name of *extroversion of the bladder*. In this condition the lower part of the abdominal wall as high as the umbilicus, and the anterior wall of the bladder are wanting, so that the posterior wall of the bladder presents on the abdominal surface, and is pushed forwards by the pressure of the viscera within the abdomen, forming a red vascular tumour on which the openings of the ureters are visible. The penis, except the glans, is rudimentary and is cleft on its dorsal surface, exposing the floor of the urethra, a condition known as *epispadias*. The pelvic bones are also arrested in development (p. 808).

When the bladder is distended, it may be ruptured by violence applied to the abdominal wall, without any injury to the bony pelvis, or it may be torn in cases of

FIG. 1076.—A vertical section of the wall of the bladder.



fracture of the pelvis. The rupture may be either intraperitoneal or extraperitoneal; that is, may implicate the superior surface of the bladder in the former case, or one of the other surfaces in the latter. Until recently intraperitoneal rupture was uniformly fatal, but now abdominal section and suturing the rent with Lambert's suture are resorted to, with a very considerable amount of success. The sutures are inserted only through the peritoneal and muscular coats in such a way as to bring the serous surfaces at the margins of the wound into apposition.

The muscular coat of the bladder undergoes hypertrophy in cases in which there is any obstruction to the flow of urine. Under these circumstances the bundles of which the muscular coat consists become much increased in size, and, interlacing in all directions, give rise to what is known as the *fasciculated bladder*. Between these muscular bundles the mucous membrane may bulge out, forming sacculi, constituting the *sacculated bladder*, and in these little pouches phosphatic concretions may collect, forming *encysted calculi*.

Various forms of tumour have been found springing from the wall of the bladder. The commonest innocent tumour is the villous papilloma. Of the malignant tumours, epithelioma is the most common. In doubtful cases the cystoscope proves a valuable aid in diagnosis. This instrument consists of a tube in which is fixed a small electric light, the wires of which run through the shaft of the instrument. Upon introducing this down the urethra, the bladder can be examined with the eye, and a villous growth or other tumour, a calculus, or an ulcer can be detected; or the orifices of the ureters can be examined, and renal hæmaturia diagnosed, and it can be definitely settled from which kidney the blood comes. Again, the presence of a minute tuberculous ulceration near the mouth of the ureter on the affected side may establish the diagnosis, not only of tuberculous kidney, but also of the side in which the disease is located. The cystoscope can be used to catheterise the ureter, for the purpose of obtaining a specimen of urine from either kidney, or to ascertain the condition of both kidneys where it is proposed to remove one. Ureteric bougies opaque to x-rays can be passed up and photographed.

Puncture of the bladder may be performed either above the symphysis pubis or through the rectum, in both cases without wounding the peritoneum. The former plan is generally to be preferred, since in puncture by the rectum a permanent fistula may be left from an abscess forming between the rectum and the bladder; or pelvic cellulitis may be set up; moreover, it is exceedingly inconvenient to keep a canula in the rectum. In some cases in performing this operation the rectovesical excavation of the peritoneum has been wounded, inducing fatal peritonitis. Puncture through the rectum, therefore, has been almost completely abandoned in favour of the suprapubic route.

Access to the bladder, for the purpose of removing calculi or an enlarged prostate, is almost always effected by the suprapubic route, the old perineal operation being rarely resorted to. In the female, owing to the shortness of the urethra and its ready dilatability, calculi and foreign bodies and few growths, when of small size, may be removed by the urethral route.

Suprapubic cystotomy is performed by first injecting ten or twelve ounces of some weak antiseptic fluid into the bladder. Then, with or without distending the rectum, a vertical median incision, from 7 to 10 cm. in length, is made in the hypogastric region immediately above the symphysis, and extended between the *Pyramidales* and *Recti* until the *transversalis fascia* is reached. This is divided and some fatty tissue exposed (space of Retzius). Upon separating this, the anterior surface of the bladder will be exposed and will be recognised by its muscular fibres. A needle should be passed through its coat on either side of the spot selected for the opening, and two long pieces of silk inserted. The bladder is incised between these stays, which are held by an assistant and form a useful guide to the opening in the bladder when the fluid has escaped.

It is important that the bladder should be emptied by catheter as a routine measure in women, prior to operations on the lower part of the abdomen or pelvis. Neglect of this precaution has, not uncommonly, led to that viscus being opened by accident. Women especially are apt to acquire an chronic distension of the bladder, and the fact that some quantity of urine has been passed immediately before the operation is no guarantee that the viscus is not distended. If the accident should occur, the bladder wall must be carefully sutured before the peritoneum is opened.

THE MALE URETHRA (fig. 1072)

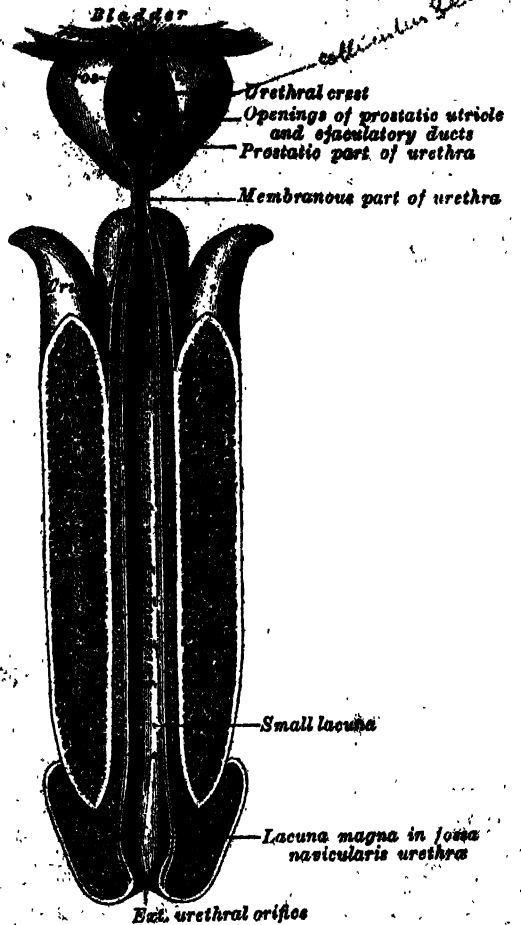
The male urethra, from 18 cm. to 20 cm. long, extends from the internal urethral orifice in the urinary bladder to the external urethral orifice at the end of the penis. It presents a double curve in the ordinary relaxed state of the penis (fig. 1072). Except during the passage of fluid along it, the urethral canal is a mere slit or cleft; in the prostatic portion the slit is transversely situated; in the membranous portion irregular or oblique; in the cavernous portion transverse; while at the external orifice it is vertical. It is divided into three portions, prostatic, membranous, and cavernous, which differ in structure and relations.

The prostatic portion, the widest and most dilatable part of the urethra, is about 2 cm. long, and runs almost vertically through the prostate from its base to a point on its anterior surface, a little above the apex. It lies nearer the anterior than the posterior surface of the prostate. It is wider in the middle than at either end, and narrowest below, where it joins the membranous portion; in transverse section it is horseshoe-shaped with the convexity directed forwards.

Upon the posterior wall or floor is a narrow longitudinal ridge, the *urethral crest* (*verumontanum*) formed by an elevation of the mucous membrane and its subjacent tissue. It is about 15 mm. long, and about 3 mm. high, and contains, according to Kobelt, muscular and erectile tissue. (When distended, it may serve to prevent the passage of the semen backwards into the bladder.) On either side of the crest is a slight depression, the *prostatic sinus*, the floor of which is perforated by the *orifices of the prostatic ducts* from the lateral lobes of the prostate; the ducts of the middle lobe open proximally to the crest. At the fore part of the urethral crest is an elevation, the *colliculus seminalis*, on which are the orifice of the prostatic utricle and the openings of the ejaculatory ducts. The *prostatic utricle* or *uterus masculinus* forms a cul-de-sac about 6 mm. long, which runs upwards and backwards in the substance of the prostate behind the middle lobe. Its walls are composed of fibrous tissue, muscular fibres, and mucous membrane, and numerous small glands open on its inner surface. It is developed from the united lower ends of the Møllerian ducts, and is therefore homologous with the uterus and vagina of the female. The ejaculatory ducts are described on p. 1170.

The membranous portion is the shortest, least dilatable, and, with the exception of the external orifice, the narrowest part of the urethra. It runs downwards and forwards, with a slight anterior concavity, from the prostate to the bulb of the urethra, perforating the urogenital diaphragm about 2.5 cm. below and behind the *punctum symphyseum*. The hinder part of the urethral bulb lies in apposition with the anterior bands of the urogenital diaphragm, but its upper portion diverges somewhat from this plane; the anterior wall of the membranous urethra is thus protected by a short distance in front of the urogenital diaphragm, and measures about 2 cm. in length, while the posterior wall, which is between the two bands of the diaphragm is only 1.25 cm. long. The membranous portion of the urethra is completely surrounded by the fibres of the *bulbospongiosus* and *ischio-cavernosus* muscles. In front of it the deep dorsal vein of the penis crosses the pelvis between the transverse ligament of the

FIG. 1077.—The male urethra laid open on its anterior (upper) surface.



pelvis and the arcuate pubic ligament; on either side near its termination are the bulbo-urethral glands. The junction of the membranous and cavernous portions of the urethra is the lowest part of the tube.

The cavernous portion is contained in the corpus cavernosum urethrae. It is about 15 cm. long, and extends from the end of the membranous portion to the external urethral orifice. Commencing below the inferior fascia of the urogenital diaphragm, it passes forwards and upwards to the front of the symphysis pubis; and then, in the flaccid condition of the penis, it bends downwards and forwards. It is narrow, with a uniform diameter of about 6 mm. in the body of the penis; it is dilated behind, within the bulb, and again anteriorly within the glans penis, where it forms the *fossa navicularis urethrae*.

The external urethral orifice is the most contracted part of the urethra; it is a vertical slit, about 6 mm. long, bounded on either side by two small labia.

The lining membrane of the urethra, especially on the floor of the cavernous portion, presents the orifices of numerous mucous glands and follicles situated in the submucous tissue, and named the *urethral glands* (Littre). Besides these there are a number of small pit-like recesses, or *lacunae*, of varying sizes. Their orifices are directed forwards, and may intercept the point of a catheter in its passage along the canal. One lacuna, larger than the rest, is situated on the upper surface of the fossa navicularis; it is called the *lacuna magna*. The bulbo-urethral glands open into the cavernous portion about 2.5 cm. in front of the urogenital diaphragm.

Structure.—The urethra is composed of mucous membrane, supported by a submucous tissue which connects it with the various structures through which it passes.

The mucous coat forms part of the genito-urinary mucous membrane. It is continuous with the mucous membrane of the bladder, and externally with the skin covering the glans penis; it is prolonged into the ducts of the glands which open into the urethra, viz. the bulbo-urethral glands and the glands of the prostate; and into the ductus deferentes and vesiculae seminales, through the ejaculatory ducts. In the cavernous and membranous portions the mucous membrane is arranged in longitudinal folds when the tube is empty. Small papillae are found upon it, near the external urethral orifice; its epithelial lining is of the columnar variety except near the external orifice, where it is squamous and stratified.

The submucous tissue consists of a vascular erectile layer; outside this is a layer of unstripped muscular fibres, arranged in a circular direction, which separates the mucous membrane and submucous tissue from the tissue of the corpus cavernosum urethrae.

The lymphatic vessels of the urethra are described on p. 784.

Applied Anatomy.—The urethra may be ruptured by the patient falling astride of any hard substance and striking his perineum, so that the urethra is crushed against the pubic arch. Bleeding will at once take place from the urethra, and this, together with the bruising in the perineum and the history of the accident, will point to the nature of the injury. Rupture of the urethra is due in other cases to the perforation of a peri-urethral abscess. Extravasation of urine most frequently takes place into the perineum in front of the inferior fascia of the urogenital diaphragm, i.e. under the fascia of Colles. Both these layers of fascia are attached firmly to the ischiopubic rami. It is clear, therefore, that when extravasation of fluid takes place between them, it cannot pass backwards, because the two layers are continuous with each other around the Transversi perinei superficiales; it cannot extend laterally, on account of the connexion of these layers to the rami of the os pubis and ischium; it cannot find its way into the pelvis, because the opening into this cavity is closed by the urogenital diaphragm, and, therefore, so long as these two layers remain intact, the only direction in which the fluid can make its way is forwards into the areolar tissue of the scrotum and penis, and thence on to the anterior wall of the abdomen.

Gonorrhoea is an acute and very prevalent inflammatory infection of the mucous membrane of the urethra. The causative organisms (gonococci) pass through the mucous membrane into the submucous tissue, and most serious complications and results may follow. In most cases the disease remains limited to the part of the urethra in front of the urogenital diaphragm, but in some (about 10 per cent.) the 'posterior urethra' becomes involved in the process, leading to an inflammation of the openings of the prostatic follicles. Such a condition is apt to continue as a very chronic form of prostatitis, and in many cases the infection will spread along the ductus deferentes, giving rise to epididymitis.

The anatomy of the urethra is of considerable importance in connexion with the passage of instruments into the bladder. Otis was the first to point out that the urethra is capable of great dilatation, so that, excepting through the external urethral orifice, an instrument corresponding to 18 English gauge (20 French) can usually be passed without

damage. The external orifice of the urethra is not so dilatable, and therefore may require slitting. A recognition of this dilatability caused Bigelow to modify very considerably the operation for crushing a stone in the bladder. In passing catheters, especially fine ones, the point of the instrument should be kept as far as possible along the upper wall of the canal, as otherwise it is very liable to enter one of the lacunæ.

Stricture of the urethra is a disease of very common occurrence, and is generally situated in the cavernous part of the urethra, just in front of the membranous portion but in a very considerable number of cases in the antescrotal part of the canal. The stricture usually results from the contraction of inflammatory products in the submucous tissue, the result, in the vast majority of all cases, of a prolonged gleet following gonorrhoea. Urethral stricture, however, follows rupture of that tube resulting from falls on the perineum, and in this variety is very dense, and is a most unsatisfactory condition with regard to treatment. Congenital stricture is also occasionally met with, and in such cases multiple strictures may be present throughout the whole length of the cavernous portion.

Congenital defects of the urethra occur occasionally. The one most frequently met with is where there is a cleft on the floor of the urethra owing to an arrest of union in the middle line. This is known as *hypospadias*, and the cleft may vary in extent. The simplest and by far the most common form is where the deficiency is confined to the glans penis. The urethra ends at the point where the extremity of the prepuce joins the body of the penis, in a small valve-like opening. The prepuce is also cleft on its under surface and forms a sort of hood over the glans. There is a depression on the glans in the position of the normal meatus. This condition produces no disability and requires no treatment. In more severe cases the cavernous portion of the urethra is cleft throughout its entire length, and the opening of the urethra is at the point of junction of the penis and scrotum. The under surface of the penis in the middle line presents a furrow lined by a moist mucous membrane, on either side of which is often more or less dense fibrous tissue stretching from the glans to the opening of the urethra, which prevents complete erection taking place. Great discomfort is induced during micturition, and sexual connexion is impossible. The condition may be remedied by a series of plastic operations. The worst form of this condition is where the urethra is deficient as far back as the perineum, and the scrotum is cleft. The penis is small and bound down between the two halves of the scrotum, so as to resemble a hypertrophied clitoris. The testes are often retained in the abdomen. The condition of parts, therefore, very much resembles the external organs of generation of the female, and many children the victims of this malformation have been brought up as girls. The halves of the scrotum, deficient of testes, resemble the labia, the cleft between them looks like the orifice of the vagina, and the diminutive penis is taken for an enlarged clitoris. There is no remedy for this condition.

A much more uncommon form of malformation is where there is an apparent deficiency of the upper wall of the urethra; this is named *epispadias*. The deficiency may vary in extent; when it is complete the condition is associated with extroversion of the bladder (p. 1159). In less extensive cases, where there is no extroversion, there is an infundibuliform opening into the bladder. The penis is usually dwarfed and turned upwards, so that the glans lies over the opening.

THE FEMALE URETHRA (fig. 1074)

The female urethra is about 4 cm. long and 6 mm. in diameter. It begins at the internal urethral orifice of the bladder, and runs downwards and forwards behind the symphysis pubis, imbedded in the anterior wall of the vagina. It perforates the urogenital diaphragm and ends at the external urethral orifice, an anteroposterior slit which has rather prominent margins, and is situated directly in front of the vaginal opening and about 2.5 cm. behind the glans clitoridis. Except during the passage of fluid the anterior and posterior walls of the urethra are in apposition, and the lining membrane is thrown into longitudinal folds, one of which, placed on the posterior wall of the canal, is termed the urethral crest. Many small urethral glands open into the urethra.

Structure.—The urethra consists of three coats: muscular, erectile, and mucous.

The muscular coat is continuous with that of the bladder; it extends the whole length of the tube, and consists of circular fibres. In addition to this, between the superior and inferior fasciæ of the urogenital diaphragm, the female urethra is surrounded by the sphincter urethrae membranaceus, as in the male.

A thin layer of spongy erectile tissue, containing a plexus of large veins, intermixed with bundles of unstriated muscular fibres, lies immediately beneath the mucous coat.

The mucous coat is pale; it is continuous externally with that of the vulva, and internally with that of the bladder. It is lined by stratified squamous epithelium, which becomes transitional near the bladder. Its external orifice is surrounded by a few mucous follicles.

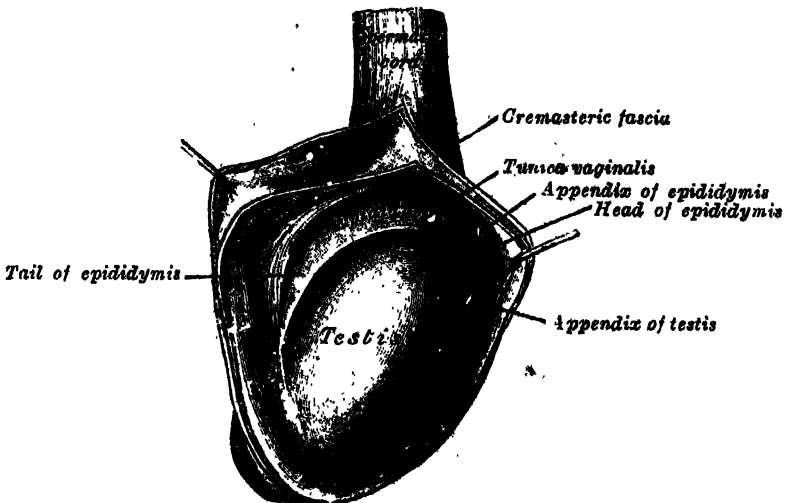
THE MALE GENITAL ORGANS

The male genital organs include the *testes* and *epididymis*, the *ductus deferentes*, the *vesiculæ seminales*, the *ejaculatory ducts*, and the *penis*, together with the following accessory structures, viz. the *prostate* and the *bulbo-urethral glands*.

THE TESTES

The *testes*, the reproductive glands in the male, are suspended in the scrotum by the spermatic cords, the left testis hanging somewhat lower than its fellow. The average dimensions of the testis are from 4 cm. to 5 cm. in

FIG. 1078.—The right testis, exposed by laying open the tunica vaginalis.



length, 2.5 cm. in breadth, and 3 cm. in the anteroposterior diameter; its weight varies from 10.5 gm. to 14 gm. Each testis is of an oval form (fig. 1078), compressed laterally, and has an oblique position in the scrotum; the upper extremity is directed forwards and a little lateralwards; the lower, backwards and a little medialwards; the anterior convex border looks forwards and downwards; the posterior or straight border, to which the spermatic cord is attached, backwards and upwards.

The anterior border and lateral surfaces, as well as both extremities of the testis, are convex, free, smooth, and invested by the visceral layer of the tunica vaginalis. The posterior border receives only a partial investment from that membrane. Lying upon the lateral edge of this posterior border is the *epididymis*.

Epididymis.—The epididymis consists essentially of a tortuous canal which forms the first part of the efferent duct of the testis. This canal is folded on itself and tightly packed into the form of a long, narrow, flattened body attached to the lateral part of the posterior border of the testis. It consists of a central portion, or *body*; an upper enlarged extremity, the *head* (*glans major*); and a lower pointed extremity, the *tail* (*glans minor*). The head is intimately connected with the upper end of the testis by means of the efferent ductules of the gland; the tail is connected with the lower end by cellular tissue, and a reflection of the tunica vaginalis. The lateral surfaces of the head and tail of the epididymis are free and covered by the tunica vaginalis.

The body is also completely invested by it, except at its posterior border; whilst between the body of the epididymis and the lateral surface of the testis is a pouch, named the *sinus of the epididymis* (digital fossa).

Appendages of the testis and epididymis.—On the upper extremity of the testis, just beneath the head of the epididymis, is a minute oval, sessile body, the *appendix of the testis* (hydatid of Morgagni); it is the remnant of the upper end of the Müllerian duct. On the head of the epididymis is a second small stalked appendage (sometimes duplicated); it is named the *appendix of the epididymis* (pedunculated hydatid), and is usually regarded as a detached efferent duct.

The testis is invested by three tunics: the tunica vaginalis, tunica albuginea, and tunica vasculosa.

The tunica vaginalis is the lower portion of the saccus vaginalis of the peritoneum which, in the foetus, preceded the descent of the testis from the abdomen into the scrotum. After the testis has reached the scrotum the upper part of the saccus vaginalis, viz. from the abdominal inguinal ring to within a short distance of the testis, contracts and undergoes obliteration. The lower portion remains as a shut sac, which invests the surface of the testis, and is reflected on to the internal surface of the scrotum; hence it may be described as consisting of a visceral and a parietal lamina.

The *visceral lamina* covers the greater part of the testis and epididymis. It lines the sinus of the epididymis and passes as two folds, one from the head and the other from the tail of the epididymis, to the testis; these folds are termed the *superior and inferior ligaments of the epididymis*. From the posterior border of the testis it is reflected on to the internal surface of the scrotum.

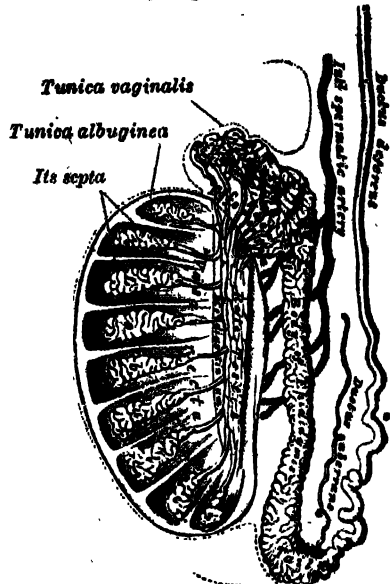
The *parietal lamina* is more extensive than the visceral, extending upwards for some distance in front and on the medial side of the cord, and reaching below the testis. The inner surface of the tunica vaginalis is smooth, and covered by a layer of endothelial cells. The interval between the visceral and parietal laminae constitutes the cavity of the tunica vaginalis.

The obliterated portion of the saccus vaginalis may frequently be seen as a fibrous thread in the areolar tissue in front of the spermatic cord; sometimes this thread may be traced from the upper end of the inguinal canal, where it is connected with the peritoneum, down to the tunica vaginalis; sometimes it is lost on the spermatic cord. In some cases the upper part of the saccus vaginalis is not obliterated, and the peritoneal cavity then communicates with the tunica vaginalis. This may give rise to one of the varieties of oblique inguinal hernia (p. 1125). In other cases the upper part of the saccus vaginalis may persist as a minute canal leading from the peritoneal cavity to that of the tunica vaginalis.

The tunica albuginea forms a fibrous covering for the testis. It is a dense membrane of a bluish-white colour, composed of interlacing bundles of white fibrous tissue. It is covered by the tunica vaginalis, except at the head and tail of the epididymis, and along the posterior border of the testis, where the testicular vessels and nerves enter the gland. It is applied to the tunica vasculosa over the glandular substance of the testis, and, at its posterior border, is reflected into the interior of the gland, forming an incomplete vertical septum, called the *mediastinum testis* (*corpus Highmori*).

The *mediastinum testis* extends from the upper to near the lower extremity of the gland, and is wider above than below. From its front and sides numerous

FIG. 1079.—A vertical section of the testis, to show the arrangement of the ducts. (Diagrammatic.)

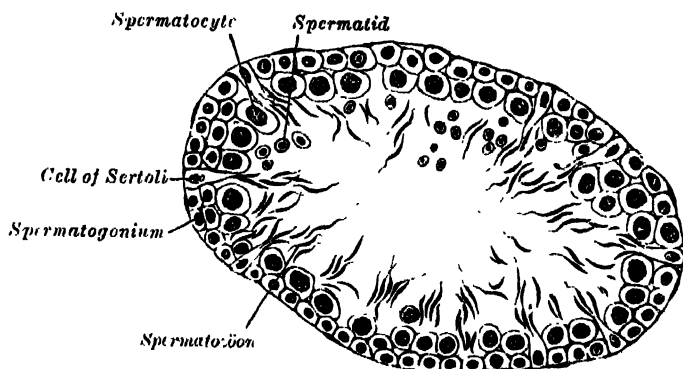


imperfect septa (*septula testis*) are given off, which radiate towards the surface of the testis, and are attached to the deep aspect of the tunica albuginea. They incompletely divide the testis into a number of cone-shaped lobules (*lobuli testis*). The bases of the lobules are at the surface of the testis, and their apices converge to the mediastinum. The mediastinum supports the vessels and ducts of the testis in their passage to and from the substance of the gland.

The *tunica vasculosa* is the vascular layer of the testis, consisting of a plexus of blood-vessels held together by delicate areolar tissue. It lines the tunica albuginea and clothes the *septula testis*, and therefore forms an investment to all the lobules of the testis.

Structure.—The glandular structure of the testis consists of the *lobuli testis* (fig. 1079). Their number, in a single testis, is estimated by Berres at 250, and by Krause at 400. They differ in size according to their position, those in the middle of the testis being larger and longer. Each lobule consists of from one to three, or more, minute convoluted

FIG. 1080.—A transverse section through a tubule of the testis of a rat. $\times 250$.

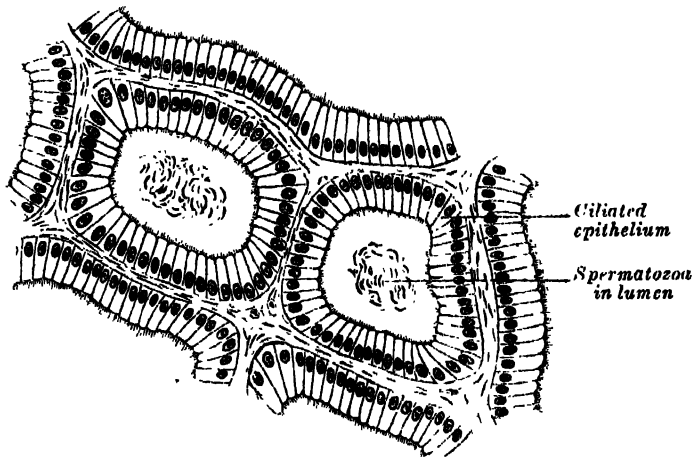


tubes, the *tubuli seminiferi contorti*. When the tubules have been unravelled by careful dissection under water, they are seen to commence either by free caecal ends or by anastomotic loops. They are supported by loose connective tissue which contains here and there groups of *interstitial cells* containing yellow pigment granules. The total number of tubules is estimated by Lauch at 840, and the average length of each is 70 cm. to 80 cm. Their diameter varies from 0.12 mm. to 0.3 mm. The tubules are pale in colour in early life, but in old age they acquire a deep yellow tinge from containing much fatty matter. Each tubule (fig. 1080) consists of a basement layer formed of laminated connective tissue containing numerous elastic fibres, with flattened cells between the layers, and covered externally by a layer of flattened epithelioid cells. Within the basement membrane are epithelial cells arranged in three irregular layers. 1. An outer layer of cubical cells, with small nuclei; some of these enlarge to become *spermatogonia*. The nuclei of some of the spermatogonia may be seen to be in process of indirect division (p. 2), and in consequence of this, daughter cells are formed, which constitute the second zone. 2. Larger polyhedral cells, with clear nuclei, arranged in two or three layers; these are the *intermediate cells* or *spermatocytes*. Most of these cells are in a condition of indirect division, and the cells which result from this division form those of the next layer. 3. The third layer of cells consists of the *spermatids*, each of which becomes a *spermatozoon*. The spermatids are small polyhedral cells, the nucleus of each containing half the usual number of chromosomes. The changes which occur during the conversion of the spermatids into spermatozoa are described on pp. 45, 46 and illustrated in fig. 65, p. 46. In addition to these three layers of cells others, termed the *supporting cells*, or *cells of Sertoli* are seen. They are elongated and columnar, and project inwards from the basement membrane towards the lumen of the tube. As development of the spermatozoa proceeds, the latter group themselves upon the inner extremities of the supporting cells. Ultimately the spermatozoa are liberated and set free. The structure of the spermatozoa is described on p. 44.

In the apices of the lobules, the tubules become less convoluted, assume a nearly straight course, and unite together to form from twenty to thirty larger straight ducts, of about 0.5 mm. in diameter, called *tubuli seminiferi recti* (fig. 1079).

The *tubuli seminiferi recti* enter the fibrous tissue of the mediastinum, and pass upwards and backwards, forming, in their ascent, a close network of anastomosing tubes which are merely channels in the fibrous stroma, lined by flattened epithelium, and having no proper walls; this network is named the *rete testis*. At the upper end of the mediastinum, the vessels of the rete testis terminate in from twelve to twenty ducts, the *ductuli efferentes testis*; they perforate the tunica albuginea, and carry the seminal fluid from the testis to the epididymis. Their course is at first straight; they then become enlarged and exceedingly convoluted, and form a series of conical masses, the *lobules of the epididymis (coni vasculosi)*, which together constitute the head of the epididymis. Each lobule consists of a single convoluted duct, from 15 cm. to 20 cm. in length. Opposite the bases of the lobules the canals open into a single duct, which constitutes, by its complex convolutions, the body and tail of the *epididymis*. When the convolutions are unravelled, this tube measures upwards of 6 metres in length; it increases in diameter and thickness as it approaches the tail of the epididymis where it becomes the *ductus deferens*. The convolutions are held together by fine areolar tissue, and by bands of fibrous tissue.

FIG. 1081.--A section of the epididymis of a guinea-pig. $\times 255$.



The ductuli efferentes and the tube of the epididymis have walls of considerable thickness, on account of the presence in them of muscular tissue which is principally arranged in a circular manner. These tubes are lined by columnar ciliated epithelium (fig. 1081).

Applied Anatomy.—The descent of the testis may be arrested. It may be retained in the abdomen; or it may be arrested at the abdominal inguinal ring, or in the inguinal canal; or it may just pass out of the subcutaneous inguinal ring without finding its way to the bottom of the scrotum. When retained in the abdomen it gives rise to no signs or symptoms, other than the absence of the testis from the scrotum. When it is retained in the inguinal canal it is subjected to pressure and may become inflamed and painful. The retained testis is probably functionally useless; so that a man in whom both testes are retained (*anorchism*) is sterile, though he may not be impotent. The absence of one testis is termed *monorchism*. When a testis is retained in the inguinal canal it is often complicated with a congenital hernia, the saccus vaginalis of the peritoneum not being obliterated. The testis may descend through the inguinal canal, but may miss the scrotum and assume some abnormal position. The most common form is where it comes to rest in the perineum. This is known as *perineal ectopia testis*. When the testis occupies an abnormal position it is very common to find concurrently a congenital hernia or a patent saccus vaginalis.

The testis may be inverted within the scrotum so that its posterior or attached border is directed forwards and the tunica vaginalis is situated behind. Should a hydrocele occur, and tapping be resorted to, the trocar may be thrust into the testis, if care be not taken beforehand to ascertain the position of the gland.

A number of instances of torsion of the spermatic cord, resulting in acute strangulation of the testis, have been recorded. In some it has been attributed to a strain or twist, and in several patients the condition has been associated with a late descent of the organ. Symptoms of this condition closely simulate those of a strangulated hernia. In consequence of the torsion the circulation is partly arrested and the organ swells and

becomes acutely painful, and the condition may be accompanied with shock and vomiting. Gangrene of the testis, however, rarely follows, and the condition if left without operation, ends in atrophy of the organ. Torsion of the body of the testis also sometimes occurs within the tunica vaginalis in those cases in which a persistent mesorchium is present.

Fluid collections of a serous character are frequently found in the scrotum. To these the term *hydrocele* is applied. The most common form is the ordinary *vaginal hydrocele*, in which the fluid is contained in the sac of the tunica vaginalis. In another form, the *congenital hydrocele*, the fluid is in the sac of the tunica vaginalis, but this sac communicates with the general peritoneal cavity owing to the non-obliteration of the upper part of the *saccus vaginalis*. A third variety, known as an *infantile hydrocele*, occurs in those cases where the *saccus vaginalis* is obliterated only, at or near the abdominal inguinal ring. It resembles the vaginal hydrocele, except as regards its shape, the collection of fluid extending up the cord into the inguinal canal. Fourthly, the *saccus vaginalis* may be obliterated both at the abdominal inguinal ring and above the epididymis, leaving a central unobliterated portion, which may become distended with fluid, giving rise to a condition known as the *encysted hydrocele of the cord*.

Encysted hydrocele of the epididymis or *spermatocele* is the name given to a cyst found in connexion with the head of the epididymis. Among its contents are found a varying number of spermatozoa, and it is probably a retention cyst of one of the tubules.

The testis requires removal for malignant or tuberculous disease, in cases of large *hernia testis*, and in some instances of incompletely descended or misplaced testis. Castration is in most cases best carried out by the 'high' operation, an incision being made through the skin and fascia in the region of the subcutaneous inguinal ring. The testis, with its deeper coverings, is pushed up into the wound and separated from the scrotal tissues. The cord is then isolated, and an aneurysm needle, armed with a ligature, passed through it, as high as is thought necessary, and the cord tied and divided. In cases of malignant and tuberculous disease, it is desirable to open the inguinal canal and tie the cord as near the abdominal ring as possible. When removing the testis in this manner the tunica vaginalis is not opened and its folds of reflection to the scrotal tissues do not need division. The whole of the tunica vaginalis is thus removed with the cord and its coverings.

Acute inflammation of the testis, or *orchitis*, is common in gonorrhœa: a chronic fibrosing form of orchitis is frequent in syphilis, and leads to shrinkage and hardening of the testis. In *tabes dorsalis* the testis often becomes quite insensitive to pressure, which, in the healthy adult, readily produces a severe and peculiar sickening sensation.

THE DUCTUS DEFERENS

The ductus deferens (*vas deferens*) is the continuation of the canal of the epididymis. Commencing at the lower part of the tail of the epididymis, it is at first very tortuous, but gradually becoming less twisted it ascends along the posterior border of the testis and medial side of the epididymis, and then runs upwards in the posterior part of the spermatic cord, and traverses the inguinal canal to the abdominal inguinal ring. Here it separates from the other structures of the cord, curves round the lateral side of the inferior epigastric artery, and ascends for about 2.5 cm. in front of the external iliac artery. It is next directed backwards and slightly downwards, and, crossing the external iliac vessels obliquely, enters the pelvic cavity, where it is continued backwards between the peritoneal membrane and the lateral wall of the pelvis, and on the medial side of the obliterated umbilical artery, the obturator nerve and vessels, and the vesical vessels. It then crosses in front of the ureter (fig. 1082), and, reaching the medial side of this tube, bends at an acute angle, and runs medialwards and slightly forwards between the fundus of the bladder and the upper end of the seminal vesicle. Reaching the medial side of the seminal vesicle, it is directed downwards and medialwards in contact with it, and gradually approaches the opposite ductus. Here it lies between the fundus of the bladder and the rectum, where it is enclosed, together with the seminal vesicle, in a sheath derived from the rectovesical portion of the fascia endopelvina. Lastly, it passes downwards to the base of the prostate, and is joined at an acute angle by the duct of the seminal vesicle to form the ejaculatory duct, which traverses the prostate behind its middle lobe and opens into the prostatic portion of the urethra, close to the orifice of the prostatic utricle. The ductus deferens presents a hard and cord-like sensation to the fingers, and is of cylindrical form. Its walls are thick, and its canal is the greater part of its extent is of extremely small calibre. At the fundus of the bladder it becomes dilated and tortuous, and this portion is termed the *ampulla*; its

terminal portion, which joins the ejaculatory duct, is again greatly diminished in calibre.

Ductuli aberrantes.—A long narrow tube, the *ductulus aberrans inferior* (was aberrans of Haller), is frequently found connected with the lower part of the canal of the epididymis, or with the commencement of the ductus deferens. Its length, when it is uncoiled, varies from 5 cm. to 35 cm., and it may be dilated towards its blind extremity, or may be of uniform diameter throughout. Its structure is similar to that of the ductus deferens. Occasionally it is found unconnected with the epididymis. A second tube, the *ductulus aberrans superior*, occurs in the head of the epididymis, and is connected with the rete testis.

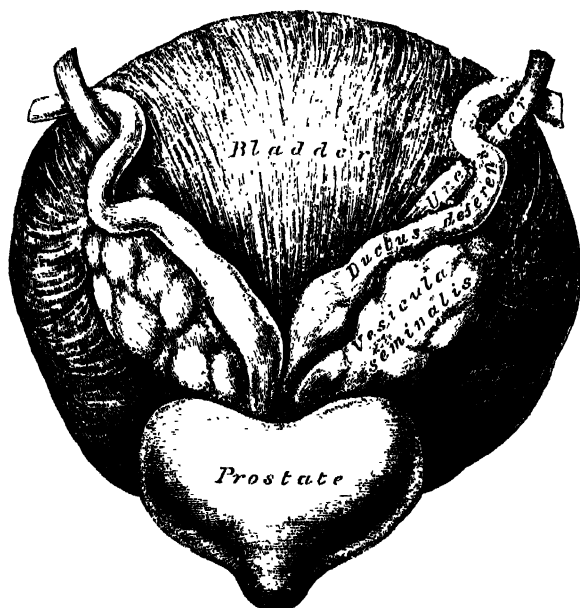
Paradidymis (organ of Giralès).—This term is applied to a small collection of convoluted tubules, situated in front of the lower part of the spermatic cord above the head of the epididymis. These tubes are lined with columnar ciliated epithelium, and probably represent the remains of a part of the Wolffian body.

Structure.—The ductus deferens consists of three coats: (1) an external or areolar coat; (2) a muscular coat, which in the greater part of the tube consists of two layers of unstriated muscular fibres: an outer, longitudinal in direction, and an inner, circular; but at the commencement of the ductus there is a third layer, consisting of longitudinal fibres, and placed between the circular stratum and the mucous membrane; (3) an internal, or mucous coat, which is pale, and arranged in longitudinal folds. The mucous coat is lined by columnar epithelium which is non-ciliated throughout the greater part of the tube; a variable portion of the testicular end of the tube is lined by two strata of columnar cells, those of the superficial layer being ciliated.

THE VESICULÆ SEMINALES AND EJACULATORY DUCTS

The *vesiculæ seminales* (fig. 1082) are two sacculated pouches, placed between the fundus of the bladder and the rectum, serving as reservoirs for the semen, and secreting a fluid to be added to the secretion of the testes.

FIG. 1082.—The fundus of the bladder with the vesiculæ seminales, &c.

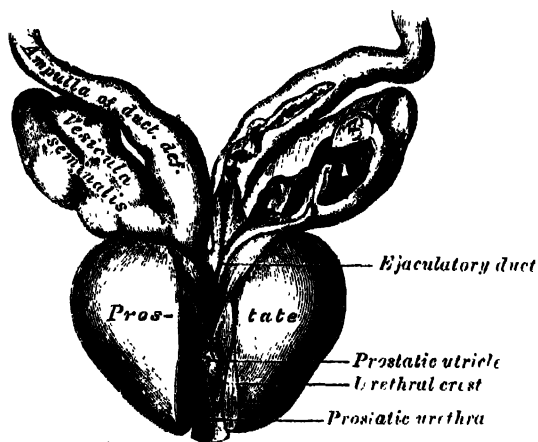


Each vesicle is somewhat pyramidal in form, the broad end being directed backwards, upwards, and lateralwards. It is usually about 5 cm. long, but varies in size, not only in different individuals, but also in the same individual on the two sides. Each vesicle consists of a single tube, coiled upon itself, and giving off several irregular cæcal diverticula (fig. 1083); the separate coils, as well as the diverticula, are connected together by fibrous tissue. When

uncolled, the tube is about the diameter of a quill, and varies in length from 10 cm. to 15 cm.; it ends above in a cul-de-sac; its lower extremity becomes constricted into a narrow straight duct, which joins with the corresponding ductus deferens to form the ejaculatory duct. The *anterior surface* is in contact with the fundus of the bladder, extending from near the termination of the ureter to the base of the prostate. The *posterior surface* rests upon the rectum,

from which it is separated by the rectovesical fascia. The vesicles diverge from each other above, and are in relation with the ductus deferentes and the terminations of the ureters, and are partly covered by peritoneum; each is enveloped in a dense fibromuscular sheath. Along the medial margin of each vesicle runs the ampulla of the ductus deferens.

FIG. 1083.—The vesiculæ seminales and the ampullæ of the ductus deferentes, seen from the front. The anterior walls of the left ampulla, left seminal vesicle, and prostatic urethra have been cut away.



Structure.—The vesiculæ seminales are composed of three coats: an *external or arcolar coat*; a *middle or muscular coat*, thinner than in the ductus deferens and arranged in two layers, an outer longitudinal and an inner circular; an *internal or mucous coat*, which is pale, of a whitish-brown colour, and presents a delicate reticular structure. The epithelium is columnar,

and in the diverticula goblet-cells are present, the secretion of which is added to the seminal fluid.

Vessels and Nerves.—The *arteries* supplying the vesiculæ seminales are derived from the middle and inferior vesical, and the middle hæmorrhoidal arteries. The *veins* and *lymphatics* accompany the arteries. The *nerves* are derived from the pelvic plexuses.

Applied Anatomy.—The vesiculæ seminales are often the seat of an extension of the disease in cases of tuberculosis of the testis, and should always be examined from the rectum, before deciding to perform castration in this affection. They also become affected in chronic posterior urethritis of gonorrhæal origin.

The **ejaculatory ducts** (fig. 1083) are two in number, one on either side of the middle line. Each is formed by the union of the duct of the vesicula seminalis with the ductus deferens, and is nearly 2 cm. long. They commence at the base of the prostate, run forwards and downwards between the middle and lateral lobes, pass along the sides of the prostatic utricle, and end on the colliculus seminalis in slit-like orifices on or just within the margins of the opening of the prostatic utricle (p. 1161). The ducts diminish in size, and also converge, towards their terminations.

Structure.—The coats of the ejaculatory ducts are extremely thin. They are: an *outer fibrous layer*, which is almost entirely lost after the entrance of the ducts into the prostate; a *layer of muscular fibres*, consisting of a thin outer circular, and an inner longitudinal layer; and *mucous membrane*.

THE SPERMATIC CORD AND ITS COVERINGS

When the testis descends through the abdominal wall into the scrotum, it drags its excretory duct, and its vessels and nerves with it. These structures meet at the abdominal inguinal ring and together form the *spermatic cord* (*funiculus spermaticus*) which suspends the testis in the scrotum, and extends from the abdominal inguinal ring to the posterior border of the testis. The left spermatic cord is rather longer than the right, and consequently the left testis hangs somewhat lower than its fellow.

The spermatic cord traverses the inguinal canal (p. 465) and in so doing is covered by the different layers which form the abdominal wall. These coverings extend downwards into the wall of the scrotum and are named, from within outwards, the *infundibuliform*, *cremasteric* and *intercrural fasciæ*.

The *infundibuliform fascia* is a thin layer which loosely invests the cord, and is derived from the *transversalis fascia* (p. 465).

The *cremasteric fascia* consists of a number of muscular fasciculi, united to one another by areolar tissue; the muscular fasciculi constitute the *Cremaster* and are continuous with the *Obliquus internus abdominis* (p. 461).

The *intercrural fascia* (*external spermatic fascia*) is a thin fibrous membrane continuous above with the tendon of the *Obliquus externus abdominis*, and prolonged downwards from the crura of the subcutaneous inguinal ring (p. 458).

Structure of the spermatic cord.—The spermatic cord is composed of arteries, veins, lymphatics, nerves, and the ductus deferens, connected together by areolar tissue.

The *arteries* of the spermatic cord are: the testicular artery, the external spermatic artery, and the artery to the ductus deferens.

The *testicular artery*, a branch of the abdominal aorta, escapes from the abdominal cavity at the abdominal inguinal ring, and accompanies the other constituents of the spermatic cord along the inguinal canal and through the subcutaneous inguinal ring into the scrotum. It then descends to the testis, and, becoming tortuous, divides into several branches, two or three of which accompany the ductus deferens and supply the epididymis, anastomosing with the artery of the ductus deferens; the others supply the substance of the testis.

The *external spermatic artery* (*cremasteric artery*) is a branch of the inferior epigastric artery. It supplies the coverings of the spermatic cord, and anastomoses with the testicular artery.

The *artery of the ductus deferens*, a branch of the superior vesical artery, is a long slender vessel which accompanies the ductus deferens, ramifying upon its coats, and anastomosing with the testicular artery near the testis.

The *testicular veins* emerge from the back of the testis, and receive tributaries from the epididymis: they unite and form a convoluted plexus, the *plexus pampiniformis*, which forms the chief mass of the cord; the vessels composing this plexus are very numerous, and ascend in front of the ductus deferens; below the subcutaneous inguinal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the abdominal inguinal ring, coalesce to form two veins. These again unite to form a single vein, which opens on the right side into the inferior vena cava, at an acute angle, and on the left side into the left renal vein, at a right angle.

The *lymphatic vessels* of the testis are described on p. 734.

The *nerves* are the spermatic plexus of the sympathetic, joined by filaments from the pelvic plexus which accompany the artery of the ductus deferens.

THE SCROTUM

The *scrotum* is a cutaneous pouch containing the testes and parts of the spermatic cords, and placed below the pubic symphysis in front of the upper parts of the thighs. It is divided on its surface into two lateral portions by a ridge, or *raphe*, which is continued forwards to the under surface of the penis, and backwards along the middle line of the perinæum to the anus; the left portion hangs lower than the right, in correspondence with the greater length of the left spermatic cord. The external appearance varies under different circumstances: thus, under the influence of warmth, and in old and debilitated persons, it is elongated and flaccid; but, under the influence of cold, and in the young and robust, it is short, corrugated, and closely applied to the testes. It consists of the skin and the dartos tunic, together with the intercrural, cremasteric and infundibuliform fasciæ, already described in connexion with the spermatic cord. Within the infundibuliform fascia is the parietal lamina of the tunica vaginalis (fig. 1084).

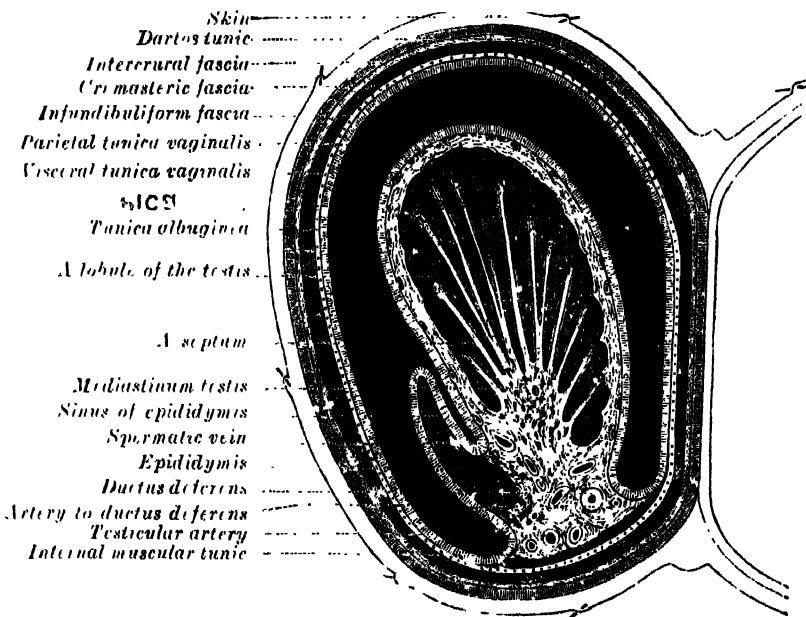
The *skin* is very thin, of a brownish colour, and generally thrown into folds or rugæ. It is provided with sebaceous follicles, the secretion of which has a peculiar odour, and is beset with thin, scattered, crisp hairs, the roots of which are visible through the skin.

The *dartos tunic* is a thin layer of non-stripped muscular fibres, continuous, around the base of the scrotum, with the superficial fascia of the groin and

of the perinæum. It sends inwards a septum, which connects the raphe to the under surface of the root of the penis, and divides the scrotal pouch into two cavities for the testes. The dartos tunic is closely united to the skin, but is connected with the subjacent parts by delicate areolar tissue, upon which it glides with the greatest facility

Vessels and Nerves.—The *arteries* supplying the scrotum are : the superficial and deep external pudendal branches of the femoral artery, the superficial perineal branch of the internal pudendal artery, and the cremasteric branch from the inferior epigastric artery. The *veins* follow the course of the corresponding arteries. The *lymphatics* end in the inguinal lymph-glands. The *nerves* are the ilio-inguinal and lumbo-inguinal branches of the lumbar plexus, the two posterior scrotal branches of the perineal nerve, and the pudendal branch of the posterior femoral cutaneous nerve.

FIG. 1084.—A transverse section through the left half of the scrotum and the left testis. The sac of the tunica vaginalis is represented in a distended condition. (Diagrammatic.) (Delépine.)



Applied Anatomy.—The scrotum forms an admirable covering for the protection of the testes. These bodies, lying suspended and loose in the cavity of the scrotum and surrounded by serous membrane, are capable of great mobility, and can therefore easily slip about within the scrotum, and thus avoid injuries from blows or squeezes. The skin of the scrotum is very elastic and capable of great distension, and on account of the looseness and amount of subcutaneous tissue, the scrotum becomes greatly enlarged in cases of œdema, to which this part is especially liable as a result of its dependent position. The scrotum is occasionally the seat of epithelioma; this is no doubt due to the rugæ on its surface, which favour the lodgment of dirt, and this, producing irritation, is the exciting cause of the disease, which is especially common in chimney-sweeps from the lodgment of soot. The disease is very much less common than it used to be; this is probably due to the better hygienic conditions of the working classes. The scrotum is also the part most frequently affected by elephantiasis.

On account of the looseness of the subcutaneous tissue, large extravasations of blood may take place from very slight injuries. It is therefore generally recommended never to apply leeches to the scrotum, since they may lead to ecchymosis, but rather to puncture one or more of the superficial veins of the scrotum in cases where local blood-letting from this part is judged to be desirable. The muscular fibres in the dartos tunic cause contraction and considerable diminution in the size of a wound of the scrotum, as after the operation of castration, and are of assistance in keeping the edges together, and covering the exposed parts.

THE PENIS

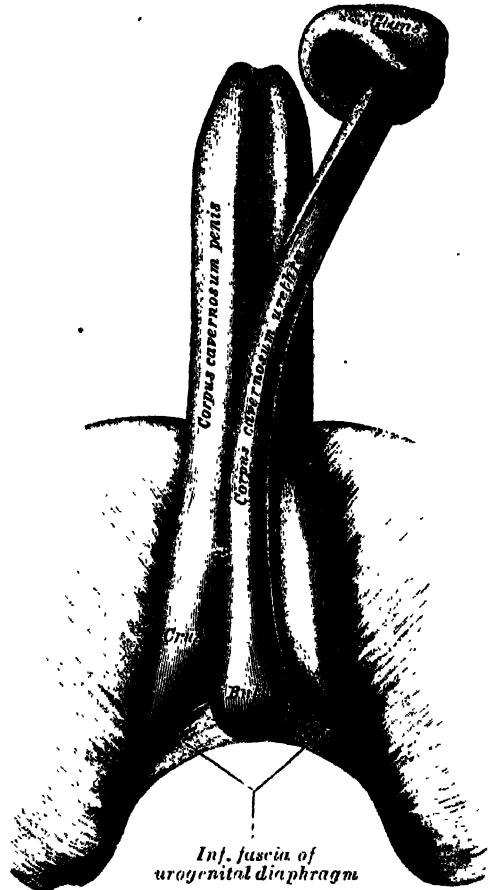
The penis is a pendulous organ suspended from the front and sides of the pubic arch and containing the greater part of the urethra. In the flaccid condition it is cylindrical in shape, but when erect assumes the form of a triangular prism with rounded angles, one side of the prism forming the dorsum. It is composed of three cylindrical masses of cavernous tissue bound together by fibrous tissue and covered with skin. Two of the masses are placed side by side, and are known as the *corpora cavernosa penis*; the third is median in position and beneath the other two; it is traversed by the cavernous part of the urethra, and is termed the *corpus cavernosum urethræ* (figs. 1085, 1086).

The *corpora cavernosa penis* form the greater part of the substance of the penis. Throughout the anterior three-fourths of their extent they lie in apposition with one another, separated only by the septum of the penis; behind, they diverge in the form of two tapering processes, known as the *crura*, which are firmly connected to the rami of the pubic arch. Traced from behind forwards each crus begins as a blunt-pointed process in front of the tuberosity of the ischium. Just before it meets its fellow it presents a slight enlargement, named by Kobelt the *bulb of the corpus cavernosum penis*. Beyond this point the crus undergoes a constriction and merges into the corpus cavernosum proper, which retains a uniform diameter to its anterior end. Each corpus cavernosum penis ends abruptly in a rounded extremity some distance from the point of the penis.

The *corpora cavernosa penis* are surrounded by a strong fibrous envelope consisting of superficial and deep fibres. The superficial fibres are longitudinal in direction, and form a single tube which encloses both corpora; the deep fibres are arranged circularly round each corpus, and form by their junction in the median plane the *septum of the penis*. This septum is thick and complete behind, but is imperfect in front, where it consists of a series of vertical bands arranged like the teeth of a comb; it is therefore named the *septum pectiniforme*.

The *corpus cavernosum urethræ* (*corpus spongiosum*) contains the cavernous part of the urethra. Behind, it is expanded to form the urethral bulb, and lies in apposition with the inferior fascia of the urogenital diaphragm, from which it receives a fibrous investment. The urethra enters the bulb nearer to the upper than to the lower surface. On the lower surface of the bulb there is a median sulcus, from which a thin fibrous septum projects into the substance of the bulb and divides it imperfectly into two lateral lobes or *hemispheres*.

FIG. 1085.—The constituent cavernous cylinders of the penis. The glans penis and the anterior part of the corpus cavernosum urethræ are detached from the corpora cavernosa penis and turned to one side.

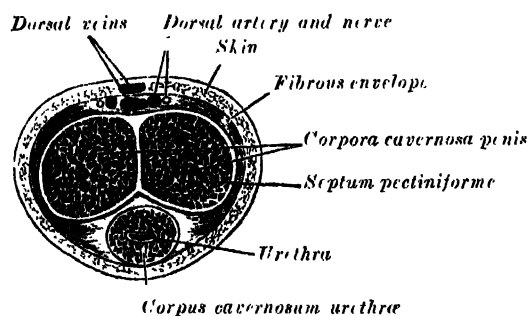


The portion of the corpus cavernosum urethræ in front of the bulb lies in a groove on the under surface of the conjoined corpora cavernosa penis. It is cylindrical in form and tapers slightly from behind forwards. Its anterior end suddenly expands to form an obtuse cone, flattened from above downwards. This expansion, termed the *glans penis*, is moulded on the rounded ends of the corpora cavernosa penis, extending farther on their upper than on their lower surfaces. Near the summit of the glans is the slit-like vertical external urethral orifice. The circumference of the base of the glans forms a rounded projecting border, the *corona glandis*, overhanging a deep *retroglandular sulcus*, behind which is the *neck* of the penis.

For descriptive purposes it is convenient to divide the penis into three regions: the root, the body, and the extremity.

The *root* of the penis is triradiate in form, consisting of the diverging crura, one on either side, and the median urethral bulb. Each crus is covered by the Ischiocavernosus, while the bulb is surrounded by the Bulbocavernosus.

FIG. 1086.—A transverse section through the penis.



The root of the penis lies in the perinæum between the inferior fascia of the urogenital diaphragm and the fascia of Colles. In addition to being attached to the fascia and the pubic rami, it is bound to the front of the symphysis pubis by the fundiform and suspensory ligaments. The fundiform ligament springs from the front of the sheath of the Rectus abdominis and the linea alba; it splits into two fasciculi which pass one on either side of the penis and unite below with the

septum of the scrotum. The upper fibres of the *suspensory ligament* pass downwards from the lower end of the linea alba, and the lower fibres from the symphysis pubis; together they form a strong fibrous band, which extends to the upper surface of the root of the penis, where it blends with the fibrous envelope of the corpora cavernosa penis.

The *body* extends from the root of the penis to the anterior end of the corpora cavernosa penis. In the body the corpora cavernosa are intimately bound to one another; a shallow groove which marks their junction on the upper surface lodges the deep dorsal vein of the penis, while a deeper and wider groove between them on the under surface contains the corpus cavernosum urethræ. The body is ensheathed by fascia, which is continuous above with the fascia of Scarpa and below with the dartos tunic of the scrotum and the fascia of Colles.

The *extremity* is formed by the glans penis, the expanded anterior end of the corpus cavernosum urethræ. It is separated from the body by the neck of the penis, which is overhung by the corona glandis.

The skin covering the penis is remarkable for its thinness, its dark colour, its looseness of connexion with the deeper parts of the organ, and its absence of adipose tissue. At the root of the penis it is continuous with the skin over the pubes, scrotum, and perinæum. At the neck of the penis it is folded upon itself to form the *prepuce* or *foreskin*, the internal layer of which is directly continuous, along the line of the neck, with the integument over the glans. Immediately behind the external urethral orifice it forms a small secondary reduplication, attached along the bottom of a depressed median raphe, which extends from the meatus to the neck; this fold is termed the *frenulum* of the prepuce. The integument covering the glans is continuous with the urethral mucous membrane at the urethral orifice. On the corona and neck there are numerous small *preputial glands* which secrete a sebaceous material of very peculiar odour and named the *smegma preputii*.

The prepuce covers a variable amount of the glans, and is separated from it by a potential sac—the *preputial sac*—which presents two shallow fossæ, one on either side of the frenulum.

Structure of the penis.—From the internal surface of the fibrous envelope of the corpora cavernosa penis, as well as from the sides of the septum, numerous bands or cords (*trabeculae*) arise, and cross the interior of the corpora cavernosa in all directions, subdividing them into a number of compartments, and giving the entire structure a spongy appearance (fig. 1086). These consist of white fibrous tissue, elastic fibres, and plain muscular fibres (fig. 1087). In them are contained numerous arteries and nerves. The component fibres which form the trabeculae are larger and stronger round the circumference than at the centres of the corpora cavernosa; they are also thicker behind than in front. The interspaces (*cavernous spaces*) are filled with blood, and are lined by a layer of flattened cells similar to the endothelial lining of veins.

The fibrous envelope of the corpus cavernosum urethrae is thinner, whiter in colour, and more elastic than that of the corpora cavernosa penis. The trabeculae are more delicate, nearly uniform in size, and the meshes between them are smaller than in the corpora cavernosa penis. The envelope of the corpus cavernosum urethrae is formed partly of unstriated muscular fibres, and a layer of the same tissue surrounds the canal of the urethra.

Vessels and Nerves.—The arteries bringing the blood to the cavernous spaces are the deep arteries of the penis and branches from the dorsal arteries of the penis, which perforate the fibrous capsule, along the upper surface, especially near the front part of the organ. On entering the cavernous structure the arteries divide into branches, which are supported and enclosed by the trabeculae. Some of these arteries end in a capillary network, the branches of which open directly into the cavernous spaces; others assume a tendril-like appearance, and form convoluted and somewhat dilated vessels, which were named by Müller *helicine arteries*. They open into the spaces, and from them are also given off small capillary branches to supply the trabecular structure. They are most abundant in the posterior parts of the corpora cavernosa.

The blood from the cavernous spaces is returned by a series of vessels, some of which emerge in considerable numbers from the base of the glans penis and converge on the dorsum of the penis to form the deep dorsal vein: others pass out on the upper surface of the corpora cavernosa and join the same vein; some emerge from the under surface of the corpora cavernosa penis and, receiving branches from the corpus cavernosum urethrae, wind round the sides of the penis to end in the deep dorsal vein; but the greater number pass out at the root of the penis and join the prostatic plexus.

The *nerves* are derived from the pudendal nerve and the pelvic plexuses. On the glans and bulb some filaments of the cutaneous nerves have Pacinian bodies connected with them, and many of them end in peculiar end-bulbs (p. 1006).

Applied Anatomy.—The penis occasionally requires removal for malignant disease. Removal of the antescrotal portion is usually all that is necessary, but sometimes it is requisite to remove the whole organ from its attachment to the pubic and ischial rami. The former operation is performed by cutting through the corpora cavernosa penis from the dorsum, and then separating the corpus cavernosum urethrae from them, dividing it at a level nearer the glans penis. The mucous membrane of the urethra is then slit up, and the edges of the flap attached to the external skin, in order to prevent contraction of the orifice, which might otherwise take place. The vessels which require to be ligatured are the deep and the dorsal arteries of the penis, and the artery of the septum. When the entire organ requires removal, the patient is placed in the lithotomy position, and an incision is made through the skin and subcutaneous tissue round the root of the penis, and carried down through the median line of the scrotum as far as the perineum. The halves of the scrotum are then separated from each other, and, a catheter having been introduced into the bladder as a guide, the corpus cavernosum urethrae below the urogenital diaphragm is separated from the corpora cavernosa penis and divided, the catheter having been withdrawn. The suspensory ligament is now severed and the crura separated from the bone with a periosteum scraper. The membranous portion of the

FIG. 1087.—A section of corpus cavernosum penis in a non-distended condition. (Cadiat.)



a. Trabeculae of connective tissue, with many elastic fibres and bundles of plain muscular tissue—some of which are cut across (c).
b. Blood-sinuses.

urethra, which has not been removed, is attached to the skin at the posterior extremity of the incision in the perinæum. The remainder of the wound is closed, free drainage being provided for.

THE PROSTATE

The prostate (fig. 1082) is a firm, partly glandular and partly muscular body, surrounding the commencement of the urethra. It is situated in the pelvic cavity, behind the lower part of the symphysis pubis, and the superior fascia of the urogenital diaphragm, and in front of the rectum. It is about the size of a chestnut and somewhat conical in shape, and presents for examination a base, an apex, a posterior, an anterior, and two lateral surfaces.

The base is directed upwards, and, for the greater part of its extent, is directly continuous with the wall of the urinary bladder: the urethra enters it nearer its anterior than its posterior border.

The apex is directed downwards, and is in contact with the superior fascia of the urogenital diaphragm.

The posterior surface is flattened from side to side and slightly convex from above downwards; it is separated by its sheath and some loose connective tissue from the rectum, and is distant about 4 cm. from the anus. Near its upper border there is a depression through which the two ejaculatory ducts enter the prostate. This depression serves to divide the posterior surface into a lower larger and an upper smaller part. The upper smaller part constitutes the middle lobe of the prostate and intervenes between the ejaculatory ducts and the urethra; it varies greatly in size, and in some cases is destitute of glandular tissue. The lower larger portion sometimes presents a shallow median furrow, which imperfectly separates it into right and left lateral lobes; these form the main mass of the gland and are directly continuous with each other behind the urethra; they are connected in front of the urethra by a band which is named the isthmus: this consists of fibromuscular tissue and is devoid of glandular substance.

The anterior surface is narrow and convex from side to side. It lies about 2 cm. behind the pubic symphysis, from which it is separated by a plexus of veins and a quantity of loose fatty tissue. It is connected to the pubic bones by the puboprostatic ligaments. The urethra emerges from this surface a little above and in front of the apex of the gland.

The lateral surfaces are prominent, and are covered by the anterior portions of the Levatores ani, which are, however, separated from the gland by a plexus of veins.

The prostate measures about 4 cm. transversely at the base, 2 cm. in its anteroposterior diameter, and 3 cm. in its vertical diameter. Its weight is about 8 gr. It is held in position by the puboprostatic ligaments; by the superior fascia of the urogenital diaphragm, which invests the prostate and the commencement of the membranous portion of the urethra; and by the anterior portions of the Levatores ani, which pass backwards from the os pubis and embrace the sides of the prostate. From the support they afford to the prostate these portions of the Levatores ani are named the *Levatores prostate*.

The prostate is perforated by the urethra and the ejaculatory ducts and contains the prostatic utricle. The urethra usually lies along the junction of its anterior with its middle third. The ducts pass obliquely downwards and forwards through the posterior part of the prostate, and open into the prostatic portion of the urethra (p. 1170).

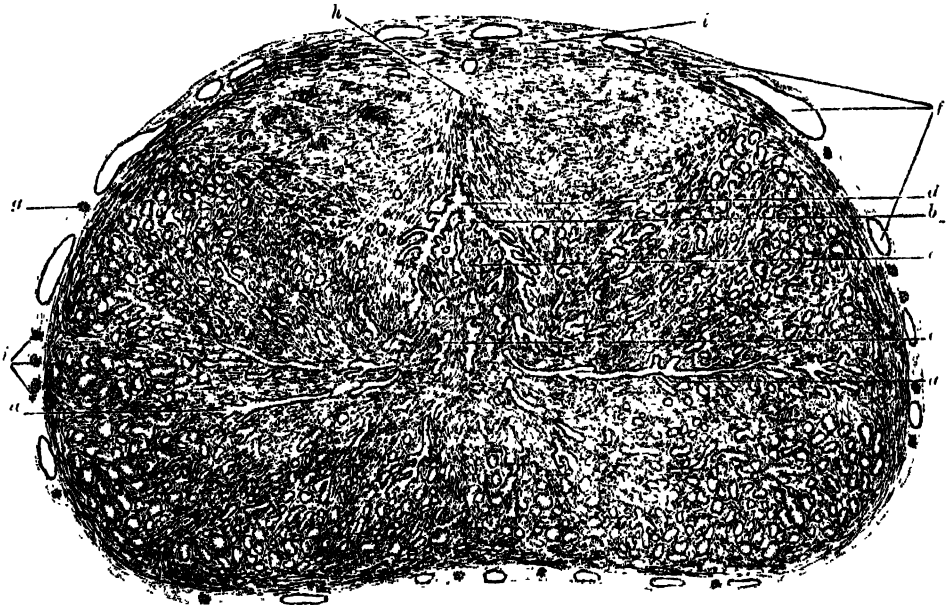
Structure (fig. 1088).—The prostate is enveloped by a thin but firm capsule, distinct from that derived from the fascia endopelvina, and separated from it by a plexus of veins. This capsule is firmly adherent to the prostate and is structurally continuous with the stroma of the gland, being composed of the same tissues, viz. non-striped muscle and fibrous tissue. The substance of the prostate is of a pale reddish-grey colour, of great density, and not easily torn. It consists of glandular substance and muscular tissue.

The muscular tissue constitutes the proper stroma of the prostate; the connective tissue being very scanty, and merely forming, between the muscular fibres, thin trabeculae in which the vessels and nerves of the gland ramify. The muscular tissue is arranged as follows: immediately beneath the capsule is a dense layer, which forms an investing sheath for the gland; around the prostatic part of the urethra is a dense layer of circular fibres, continuous above with the internal layer of the muscular coat of the

bladder, and blending below with the fibres surrounding the membranous portion of the urethra; between these two layers are strong bands of muscular tissue which decussate freely, and form meshes in which the glandular structure of the organ is imbedded. In that part of the gland which is situated in front of the urethra the muscular tissue is especially dense, and there is here little or no glandular tissue; while in that part which is behind the urethra the muscular tissue presents a wide-meshed structure, which is densest at the base of the gland—that is, near the bladder—becoming looser and more sponge-like towards the apex.

The *glandular substance* is composed of numerous follicles the lining of which frequently shows papillary elevations. The follicles open into elongated canals which join to form from twelve to twenty small excretory ducts. They are connected together by areolar tissue, supported by prolongations from the fibrous capsule and muscular stroma,

FIG. 1088.—A transverse section through a normal prostate, opposite the middle of the urethral crest. From a subject aged nineteen years. (Taylor.)



a. Longitudinal section of ducts leading from the lobules of the prostatic glands. *b.* Urethral crest. *c.* Prostatic utricle. *d.* Urethra. *e.* Ejaculatory ducts. *f.* Arteries, veins, and venous sinuses in sheath of prostate. *g.* Nerve trunks in sheath. *h.* Point of origin of fibromuscular bands encircling urethra. *i.* Zone of striated voluntary muscle on superior surface.

and enclosed in a delicate capillary plexus. The epithelium which lines the canal, and the terminal vesicles is of the columnar variety. The prostatic ducts open into the floor of the prostatic portion of the urethra, and are lined by two layers of epithelium, the inner layer consisting of columnar and the outer of small cubical cells. Small colloid masses, known as amyloid bodies, are often found in the gland tubes.

Vessels and Nerves.—The *arteries* supplying the prostate are derived from the internal pudendal, inferior vesical, and middle hæmorrhoidal arteries. Its *veins* form a plexus around the sides and base of the gland; they receive in front the dorsal vein of the penis, and and in the hypogastric veins. The *nerves* are derived from the pelvic plexus.

Applied Anatomy.—By means of the finger introduced into the rectum, the surgeon detects enlargement or other disease of the prostate; he can feel the apex of the gland, which is the guide to Cock's operation for stricture; he is enabled also by the same means to direct the point of a catheter, when its introduction is attended with difficulty either from injury or disease of the membranous or prostatic portions of the urethra. When the finger is introduced into the bowel, the surgeon may, in some cases, especially in boys, learn the position, as well as the size, of a calculus in the bladder; and in the operation for its removal, if, as is not infrequently the case, it should be lodged behind an enlarged prostate, it may be displaced from its position by pressing it upwards towards the fundus of the bladder from the rectum. The prostate is occasionally the seat of suppuration, due to either gonorrhœa or tuberculous disease. The gland is enveloped in a dense unyielding capsule, which determines the course of the abscess, and also explains the great pain which is present in the acute form of the disease. The abscess most frequently bursts

into the urethra, the direction in which there is least resistance, but may burst into the rectum, or more rarely in the perinæum. In advanced life the prostate sometimes becomes considerably enlarged and projects into the bladder so as to impede the passage of the urine. According to Messer's researches, conducted at Greenwich Hospital, it would seem that such obstruction exists in 20 per cent. of all men over sixty years of age. In some cases the condition affects principally the lateral lobes, which may undergo considerable enlargement without causing much inconvenience. In other cases it would seem that the middle lobe enlarges most, and even a small enlargement of this lobe may act injuriously, by forming a sort of valve over the internal urethral orifice, preventing the passage of the urine; and the more the patient strains, the more completely will it block the opening into the urethra. In consequence of the enlargement of the prostate, a pouch is formed at the base of the bladder behind the projection, in which urine collects, and from which it cannot be entirely expelled. For this condition *prostatectomy* is sometimes done. The bladder is opened by an incision above the symphysis pubis, the mucous membrane of the post-prostatic pouch is scratched through, and the finger is then introduced into the space between the true capsule of the prostate and outer capsule formed by the fascia endopelvicina. Separation in this plane is then carried out below and laterally until the apex of the gland is reached. The whole of the work is done with the finger, which is gradually swept round the sides until the anterior surface is reached and freed. The gland is then, by traction, displaced into the bladder and removed, usually carrying with it the greater portion of the mucous membrane of the prostatic urethra. Hæmorrhage, which may be considerable at times, is checked by hot irrigations, and the bladder is temporarily drained. Very satisfactory results have followed this operation.

The prostate can be reached from the perinæum, and in some cases the enlarged gland has been removed by this route, but the perineal approach is not usually employed except in the case of abscess of or about the gland.

THE BULBO-URETHRAL GLANDS

The **bulbo-urethral glands** (Cowper's glands) are two small, rounded and somewhat lobulated bodies, of a yellow colour, each about the size of a pea, placed laterally to the membranous portion of the urethra, between the two layers of the fascia of the urogenital diaphragm. They lie close above the urethral bulb, and are enclosed by the transverse fibres of the *Sphincter urethræ membranacæ*. They gradually diminish in size as age advances.

The excretory duct of each gland, nearly 3 cm. long, passes obliquely forwards beneath the mucous membrane, and opens by a minute orifice on the floor of the cavernous portion of the urethra about 2.5 cm. in front of the urogenital diaphragm.

Structure.—Each gland is made up of several lobules which are held together by a fibrous investment. Each lobule consists of a number of acini, lined by columnar epithelial cells.

THE FEMALE GENITAL ORGANS

The female genital organs consist of an internal and an external group. The *internal organs* are situated within the pelvis, and consist of the ovaries, the uterine tubes, the uterus, and the vagina. The *external organs* are placed below and in front of the pubic arch. They comprise the mons pubis, the labia majora et minora pudendi, the clitoris, the bulbus vestibuli, and the greater vestibular glands.

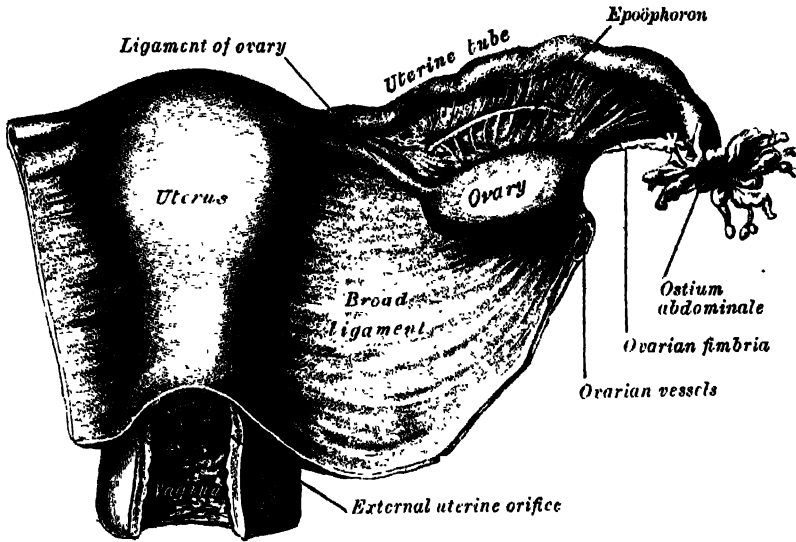


THE OVARIES

The **ovaries**, two in number, are homologous with the testes in the male. They are situated one on either side of the uterus in relation to the lateral wall of the pelvis, and attached to the back of the broad ligament of the uterus behind and below the uterine tube (fig. 1089). They are of a greyish-pink colour, and present either a smooth or a puckered uneven surface; each is about 3 cm. long, 1.5 cm. wide, and about 10 mm. thick. In the erect posture the long axis of the ovary is vertical. Each ovary presents a lateral and a medial surface, a tubal and a uterine extremity, and a mesovarian and a free border. The ovary lies in a depression, named the *ovarian fossa*, on the lateral

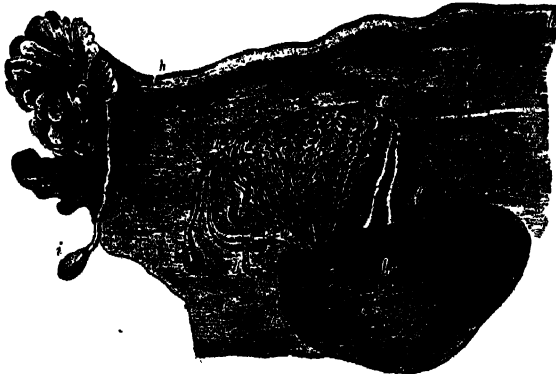
wall of the pelvis; this fossa is bounded in front by the obliterated hypogastric artery, and behind by the ureter and the uterine artery. The exact position of the ovary has been the subject of considerable difference of opinion, and the description here given applies to the ovary of the nulliparous woman; the

FIG. 1089.—The uterus and the right broad ligament, seen from behind. The broad ligament has been spread out and the ovary drawn downwards.



ovary is displaced during the first pregnancy, and probably never again returns to its original position. The *tubal extremity* (*extremitas tubaria*) is near the external iliac vein; to it are attached the ovarian fimbria of the uterine tube and a fold of peritoneum, the *suspensory ligament of the ovary*, which passes upwards over the iliac vessels and contains the ovarian vessels and nerves.

FIG. 1090.—The adult ovary, epoöphoron, and uterine tube.
(From Farre, after Kobelt.)



a, a. Epoöphoron formed from the upper part of the Wolffian body. b. Remains of the uppermost tubes sometimes forming hydatids. c. Middle set of tubes. d. Some lower atrophied tubes. e. Atrophied remains of the Wolffian duct. f. The terminal bulb or hydatid. h. The uterine tube. i. Hydatid attached to the extremity. l. The ovary.

The *uterine extremity* (*extremitas uterina*) is directed downwards towards the pelvic floor; it is usually narrower than the tubal, and is attached to the lateral angle of the uterus, immediately behind the uterine tube, by a rounded cord termed the *ligament of the ovary*, which lies within the broad ligament

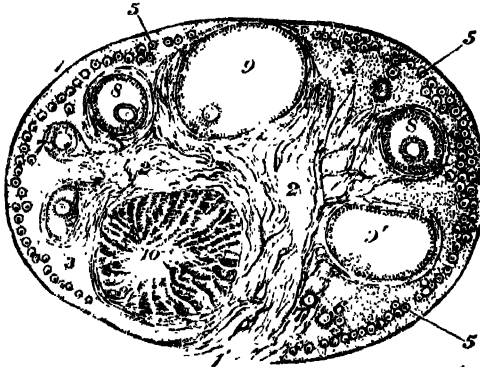
and contains some non-striped muscular fibres. The *lateral surface* is in contact with the parietal peritoneum, which lines the ovarian fossa and separates the ovary from the subperitoneal connective tissue and the obturator vessels; the *medial surface* is to a large extent covered by the uterine tube. The *mesovarian border* is straight and is directed towards the obliterated hypogastric artery; it is attached to the back of the broad ligament by a short fold named the *mesovarium*. Between the two layers of this fold the blood-vessels and nerves

pass to the hilum of the ovary.

The *free border* is convex, and is directed towards the ureter. The uterine tube arches over the ovary, running upwards in relation to its mesovarian border, curving over its tubal extremity, and then passing downwards on its free border and medial surface.

In the foetus, the ovaries are situated, like the testes, in the lumbar region near the kidneys, but they gradually descend into the pelvis (p. 152):

FIG. 1091.—A section of the ovary.
(After Schrön.)



1. Outer covering. 1'. Attached border. 2. Central stroma. 3. Peripheral stroma. 4. Blood-vessels. 5. Vesicular follicles in their earliest stage. 6, 7, 8. More advanced follicles. 9. An almost mature follicle. 10. Corpus luteum. 11. Follicle from which the ovum has escaped.

marked by a line around the anterior border of the ovary. The ovary consists of a number of vesicular ovarian follicles imbedded in the meshes of a stroma or framework.

The *stroma* is abundantly supplied with blood-vessels, and consists for the most part of spindle-shaped cells with a small amount of ordinary connective tissue. These cells have been regarded by some anatomists as unstriped muscle-cells, by others as connective tissue cells. On the surface of the organ this tissue is much condensed, and forms a layer known as the *tunica albuginea*. The stroma of the ovary also contains groups of *interstitial cells* resembling those of the testis.

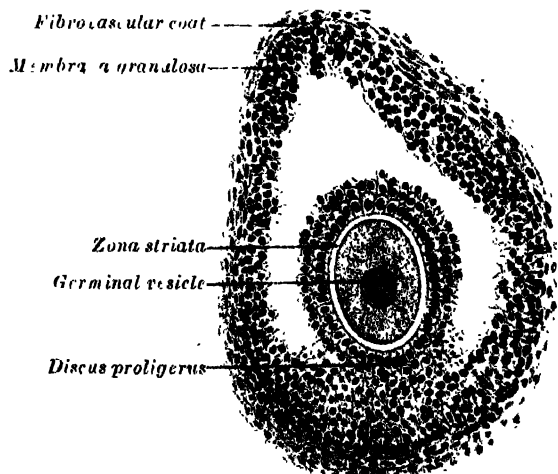
Vesicular ovarian (Graafian) follicles.

Upon making a section of an ovary, numerous vesicles of various sizes are to be seen; they are the follicles, or ovisacs containing the ova. Immediately beneath the tunica albuginea is a layer of stroma, called the *cortical layer*, characterised by the presence of a large number of ova in an early stage of development. At this stage each ovum is a spherical cell, and is surrounded by a single layer of smaller, cubical cells, the whole being about 0.25 mm. in diameter. These primitive follicles are numerous in the ovary of the child. After puberty some of them become enlarged and pass towards the interior of the ovary: the investing cells multiply, and later a cavity appears in the mass of cells thus formed.

The fully developed follicle (fig. 1092) is about 1.5 cm. in diameter, and consists of an external fibrovascular coat, connected with the surrounding stroma of the ovary by a network of blood-vessels; and an internal coat, which consists of several layers of nucleated cells, called the *membrana granulosa*. At one part of the mature follicle the cells of the *membrana granulosa* are collected into a mass which projects into the cavity

Structure (fig. 1091).—The surface of the ovary is covered by a layer of columnar cells. This epithelium gives to the ovary a dull grey colour as compared with the shining smoothness of the peritoneum; the transition between the squamous epithelium of the peritoneum and the columnar cells which cover the ovary is usually

FIG. 1092.—A section through an ovarian follicle of a cat. $\times 50$.



of the follicle. This is termed the *discus proligerus*, and in it the ovum is imbedded.* The follicle contains a transparent albuminous fluid, the *liquor folliculi*. As the follicle approaches maturity it again comes to the surface of the ovary, where it appears as a thin-walled vesicle. From the time of puberty to the end of the fruitful period of woman's life, the ovary shows a number of these vesicles. Periodically a vesicle ruptures and the ovum is set free together with the greater part of the *discus proligerus*, and is conveyed by the uterine tube to the cavity of the uterus.

The development and maturation of the follicles and ova continue uninterruptedly from puberty to the end of the reproductive period of woman's life, while their formation commences before birth.

Discharge of an ovum.—A follicle, after attaining a certain stage of development, gradually approaches the surface of the ovary and bursts; the ovum and fluid contents of the follicle are liberated on the exterior of the ovary, and carried into the uterine tube by currents set up by the movements of the cilia covering the mucous membrane of the fimbriae.

Corpus luteum.—After the discharge of the ovum a series of changes occurs within the Graafian follicle which result in the formation of a structure named the *corpus luteum*. When fully developed this consists of large cells containing yellow pigment (*luteal cells*) separated from one another by delicate trabeculae of highly vascular connective tissue which is aggregated to form a mass in the centre of the follicle devoid of cells. The luteal cells are probably derived from the epithelial cells of the Graafian follicle. These cells undergo great hypertrophy, and, in the early stages of the formation of the corpus luteum, show signs of mitosis. The connective tissue trabeculae are derived from the sheath of the follicle.

If the discharged ovum be not fertilized the corpus luteum quickly degenerates, and within two months is reduced to a small cicatrix, but if the ovum be fertilized the corpus luteum increases in size and, by the middle of pregnancy, may measure about 2.5 cm. in diameter. During the later months of pregnancy the luteal cells lose their colour, and the size of the corpus luteum diminishes, so that by the end of pregnancy its diameter is reduced to about 1 cm.†

Vessels and Nerves.—The arteries of the ovaries and uterine tubes are the ovarian from the aorta. Each anastomoses freely in the mesosalpinx with the uterine artery; it gives some branches to the uterine tube, and others which traverse the mesovarium and enter the hilum of the ovary. The veins emerge from the hilum in the form of a plexus, the *pampiniform plexus*; the ovarian vein is formed from this plexus, and leaves the pelvis in company with the artery. The nerves are derived from the hypogastric or pelvic plexus, and from the ovarian plexus, the uterine tube receiving a branch from one of the uterine nerves.

Epoöphoron (figs. 1089, 1090).—The epoöphoron or organ of Rosenmüller lies in the lateral part of the mesosalpinx between the ovary and the uterine tube, and consists of a few short tubules (*ductuli transversi*) which converge towards the ovary while their opposite ends open into a rudimentary duct, the *ductus longitudinalis epoöphori* (duct of Gärtner), which runs in the broad ligament of the uterus, parallel with the lateral part of the uterine tube.

In a small proportion of cases Gärtner's duct can be followed alongside the uterus to near the level of the internal orifice. Here it pierces the muscular wall of the uterus and descends in the cervix uteri, gradually approaching the mucous membrane, without however quite reaching it. The duct then runs downwards in the lateral wall of the vagina and ends at, or close to, the free margin of the hymen.

Paroöphoron.—The paroöphoron consists of a few scattered rudimentary tubules, best seen in the child, situated in the broad ligament between the epoöphoron and the uterus.

The ductuli transversi of the epoöphoron and the tubules of the paroöphoron are remnants of the tubules of the Wolffian body or mesonephros: the ductus longitudinalis epoöphori is a persistent portion of the Wolffian duct.

Applied Anatomy.—The inflammations which affect the ovary are merely an extension of those from the uterine tube. Ovarian new formations are of common occurrence, and are either solid or cystic; the former being the less common. The 'ovarian cysts' in the majority of cases are cystadenomata which may spring from the ovarian follicles and assume enormous dimensions; in rarer instances they arise from the tubules at the hilum of the ovary or those of the epoöphoron; in other instances a clear watery cyst forms between the layers of the broad ligament. An ovarian cyst, once diagnosed, should always be removed, as it is liable to become affected by suppuration, torsion of its pedicle, or other serious complications. The operation for its removal, badly termed *ovariotomy*, consists in opening the abdomen and delivering the cyst through the wound; the pedicle is then clamped with forceps, and the cyst is cut free. The pedicle must be transfixed and securely ligatured by an interlocking ligature, which will not slip off. The pedicle consists of an elongated part of the broad ligament, including the uterine tube and ovarian artery, and a great number of large veins. Ovariectomy for a simple uncomplicated cyst presents no special difficulties, but, in cases where there are old adhesions implicating the small intestine, it may present very great difficulties.

* The ovum is described on pp. 41 to 43.

† Consult *The Physiology of Reproduction* by F. H. A. Marshall, 1910.

THE UTERINE TUBES (figs. 1089, 1094)

The **uterine tubes** (Fallopian tubes), two in number, transmit the ova from the ovaries to the cavity of the uterus and are situated in the upper margins of the broad ligaments of the uterus. Each tube is about 10 cm. long, and one end of it opens into the superior angle of the cavity of the uterus, the other into the peritoneal cavity close to the ovary. The opening into the uterine cavity is very small, and only admits a fine bristle. The opening into the peritoneal cavity is named the *abdominal ostium*, and when its muscular wall is relaxed has a diameter of about 3 mm. The abdominal ostium is situated at the bottom of a trumpet-shaped expansion of the uterine tube, termed the *infundibulum*, the circumference of which is prolonged into a varying

FIG. 1093.—Transverse section of human uterine tube stained with hæmatoxylin and eosin. $\times 14$.



number of irregular processes, called *fimbriae*, and therefore this ostium is sometimes called the *fimbriated end* of the tube. The inner surfaces of the fimbriae are lined by mucous membrane, and in the larger fimbriae this exhibits longitudinal folds which are continuous with similar folds in the mucous lining of the infundibulum. One fimbria, longer and more deeply grooved than the others, is attached to the tubal extremity of the ovary, and is named the *ovarian fimbria*. The infundibulum opens into the *ampulla* of the tube, which is thin-walled and tortuous and forms rather more than half the entire length of the tube. The ampulla is succeeded by the *isthmus*, which is round and cord-like and constitutes approximately the medial third of the tube. The part continued from the isthmus through the wall of the uterus is about 1 cm. long, and is named the *pars uterina tube*.

The uterine tube is directed lateralwards as far as the uterine extremity of the ovary, and then ascends along the mesovarian border of the ovary to the tubal extremity, over which it arches; finally it turns downwards and ends in relation to the free border and medial surface of the ovary. In connexion with the fimbriae of the uterine tube, or with the broad ligament close to them, there are frequently one or more small pedunculated vesicles; these are termed the *appendices vesiculosae* (hydatids of Morgagni).

Structure (fig. 1093).—The uterine tube consists of three coats: serous, muscular, and mucous. The *external* or *serous coat* is peritoneal. The *middle* or *muscular coat* consists

of an external longitudinal and an internal circular layer of non-striped muscular fibres continuous with those of the uterus. The *internal* or *mucous coat* is continuous with the mucous lining of the uterus, and, at the abdominal ostium of the tube, with the peritoneum. It is thrown into longitudinal folds, which in the ampulla are much more extensive than in the isthmus. The lining epithelium is columnar and ciliated. This form of epithelium is also found on the inner surfaces of the fimbriae; while on the outer or serous surfaces of these processes the epithelium gradually merges into the endothelium of the peritoneum.

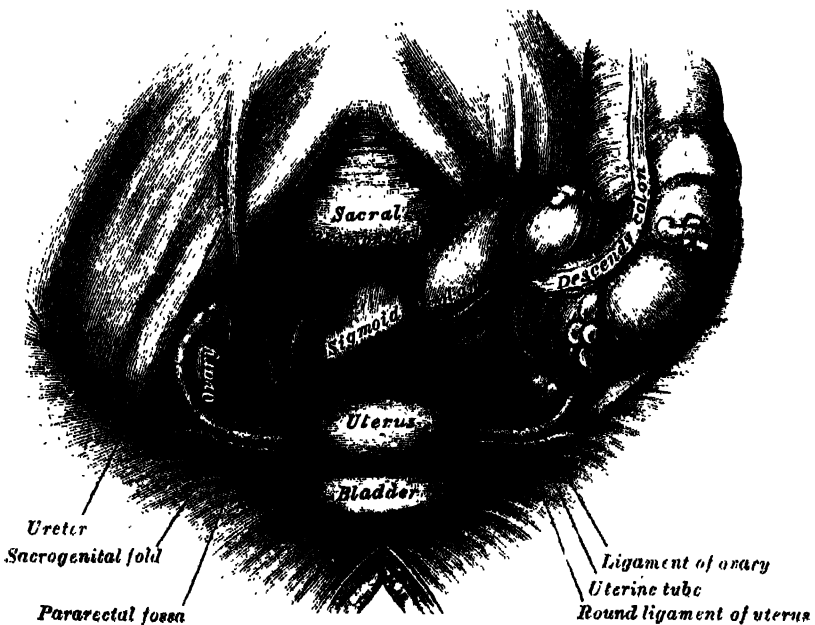
Applied Anatomy.—The majority of the diseases of the uterine tube are due to infections which have spread by way of the vagina and uterus, and the disease often does not stop at the uterine tube, but passes on to the peritoneum, giving rise to acute general peritonitis, or a localised condition termed *perimetritis* that may be acute or chronic. Perimetritis is often followed by various painful conditions, which are due to the peritoneal adhesions resulting from the inflammation of the serous membrane, and which persist throughout life. Tubal inflammation (*salpingitis*) is usually the result of an infection either by the gonococcus, or by septic organisms implanted at the time of labour or abortion. In many cases the fimbriated ends of the tubes become closed by adhesions, pus collects in the tubes, and a *pyosalpinx* results.

Fertilisation of the ovum (p. 47) is believed to occur in the uterine tube, and the fertilised ovum is then normally passed on into the uterus; the ovum, however, may adhere to and undergo development in the tube, giving rise to the commonest variety of *ectopic gestation*. In such cases the amnion and chorion are formed, but a true decidua is never present; and the gestation usually ends by extrusion of the ovum through the abdominal ostium, although it is not uncommon for the tube to rupture into the peritoneal cavity, this being accompanied by severe hæmorrhage, and needing surgical interference.

THE UTERUS (figs. 1089, 1094, 1095)

The *uterus*, or *womb*, is a hollow, thick-walled, muscular organ situated in the pelvic cavity between the urinary bladder and the rectum. Into its upper part the uterine tubes open, one on either side, while below, its cavity

FIG. 1094:—The female pelvis and its contents, seen from above and in front.



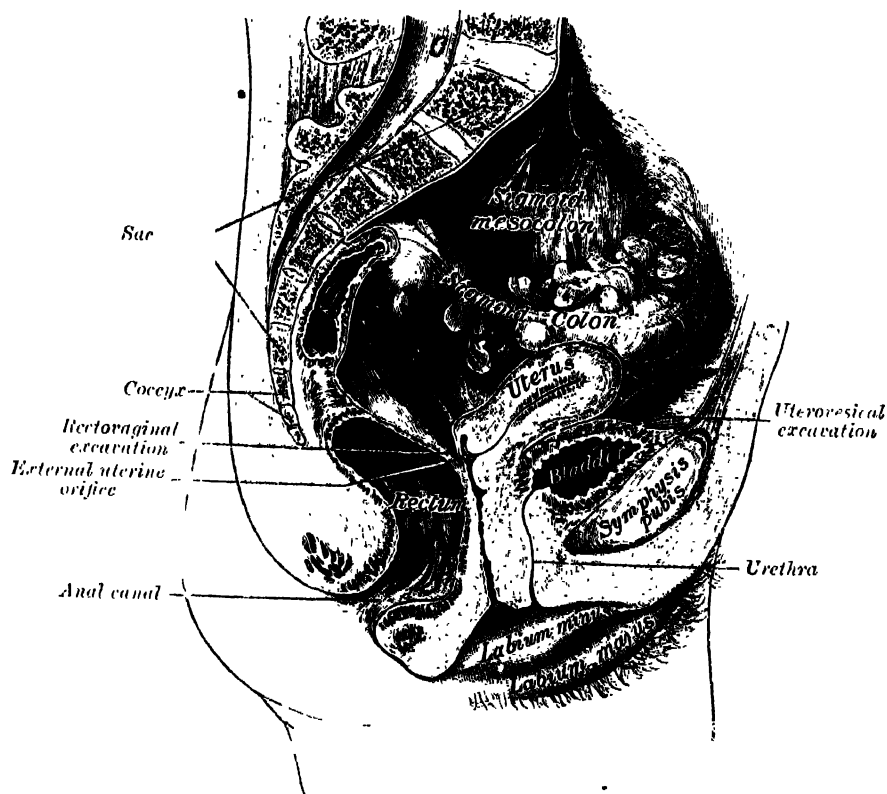
communicates with that of the vagina. When the ova are discharged from the ovaries they are carried to the uterine cavity through the uterine tubes. If an ovum be fertilised it imbeds itself in the uterine wall and is normally retained in the uterus until prenatal development is completed, the uterus undergoing changes in size and structure to accommodate itself to the needs

of the growing embryo. After parturition the uterus returns almost to its former condition, but certain traces of its enlargement remain. For general descriptive purposes the adult virgin uterus is taken as the type form.

In the virgin state the uterus is flattened from before backwards and is pyriform in shape, with the apex directed downwards and backwards. It lies between the bladder below and in front and the sigmoid colon and rectum above and behind, and is completely within the pelvis, its base being below the level of the superior pelvic aperture. Its upper part is suspended by the broad and the round ligaments, while its lower portion is imbedded in the fibrous tissue of the pelvis.

The long axis of the uterus usually lies approximately in the axis of the superior pelvic aperture, but as the organ is freely movable its position varies

FIG. 1095. --A median sagittal section of the female pelvis.



with the state of distension of the bladder and rectum. Except when much displaced by a distended bladder, it forms a forward angle with the vagina, since the axis of the vagina corresponds to the axes of the cavity and inferior aperture of the pelvis.

The uterus measures about 7.5 cm. in length, 5 cm. in breadth at its upper part, and nearly 2.5 cm. in thickness; it weighs from 30 to 40 gm. It is divisible into two portions. On the surface, a little below the middle, is a slight constriction, known as the *isthmus*, and corresponding to this in the interior is a narrowing of the uterine cavity, the *internal orifice* of the uterus. The portion above the isthmus is termed the *body*, and that below, the *cervix*. The part of the body which lies above a plane passing through the points of entrance of the uterine tubes is known as the *fundus*.

Body.—The body gradually narrows from the fundus to the isthmus.

The *vesical* or *anterior surface* is in apposition with the urinary bladder. It is flattened and covered by peritoneum, which is reflected on to the bladder to form the vesico-uterine excavation.

The *intestinal* or *posterior surface* is convex transversely, and is covered by peritoneum, which is continued downwards on to the cervix uteri and the upper part of the vagina. It is in relation with the sigmoid colon, from which it is usually separated by some coils of small intestine.

The *fundus* is convex in all directions, and covered by peritoneum continuous with that on the vesical and intestinal surfaces. On it rest some coils of small intestine, and occasionally the distended sigmoid colon.

The *lateral margins* are slightly convex. At the upper end of each the uterine tube pierces the uterine wall. Below and in front of this point the round ligament of the uterus is fixed, while below and behind it is the attachment of the ligament of the ovary. These three structures lie within a fold of peritoneum which is reflected from the margin of the uterus to the wall of the pelvis, and is named the broad ligament.

Cervix.—The cervix is the lower constricted segment of the uterus. It is somewhat conical in shape, with its truncated apex directed downwards and backwards, but is slightly wider in the middle than above or below. Owing to its relationships it is less freely movable than the body, so that its long axis is seldom in the same straight line as that of the body. The long axis of the uterus as a whole presents the form of a curved line with its concavity forwards, or in extreme cases may present an angular bend at the region of the isthmus uteri.

The cervix projects through the anterior wall of the vagina, which divides it into an upper, supravaginal portion, and a lower, vaginal portion.

The *supravaginal portion* is separated in front from the bladder by cellular tissue (*parametrium*), which extends also on to the sides of the cervix, and lateralwards between the layers of the broad ligaments. The uterine arteries reach the margins of the cervix in this fibrous tissue, while on either side the *ureter* runs downwards and forwards in it at a distance of about 2 cm. from the cervix. *Posteriorly*, the supravaginal cervix is covered by peritoneum, which is prolonged below on to the posterior vaginal wall, whence it is reflected on to the rectum, forming the recto-uterine excavation. It is in relation with the rectum, from which it may be separated by coils of small intestine.

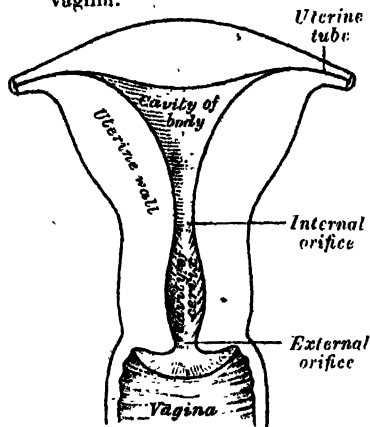
The *vaginal portion* of the cervix projects into the anterior wall of the vagina between the vaginal fornices. On its projecting rounded extremity is a small, depressed, somewhat circular aperture, the *external orifice* of the uterus, through which the cavity of the cervix communicates with that of the vagina. The external orifice is bounded by two lips, an anterior and a posterior, of which the anterior is the shorter and thicker, although, on account of the slope of the cervix, it projects lower than the posterior. Normally both lips are in contact with the posterior vaginal wall.

Interior of the uterus (fig. 1096).—The cavity of the uterus is small in comparison with the size of the organ.

The *cavity of the body* is a mere slit, flattened from before backwards. It is triangular in shape, the base being formed by the internal surface of the fundus between the orifices of the uterine tubes, the apex by the internal orifice of the uterus; through this orifice the cavity of the body communicates with the canal of the cervix.

The *canal of the cervix* is somewhat fusiform, flattened from before backwards, and broader at the middle than at either end. It communicates above, through the internal orifice, with the cavity of the body, and below, through the external orifice, with the vaginal cavity. The wall of the canal presents an anterior and a posterior longitudinal ridge, from each of which proceed a number of small oblique columns, the *palmate folds*, giving the

FIG. 1096.—The posterior half of the uterus and upper part of the vagina.



appearance of branches from the stem of a tree; to this arrangement the name *arbor vitae uterina* is applied. The folds on the two walls are not opposed, but fit between one another so as to close the cervical canal.

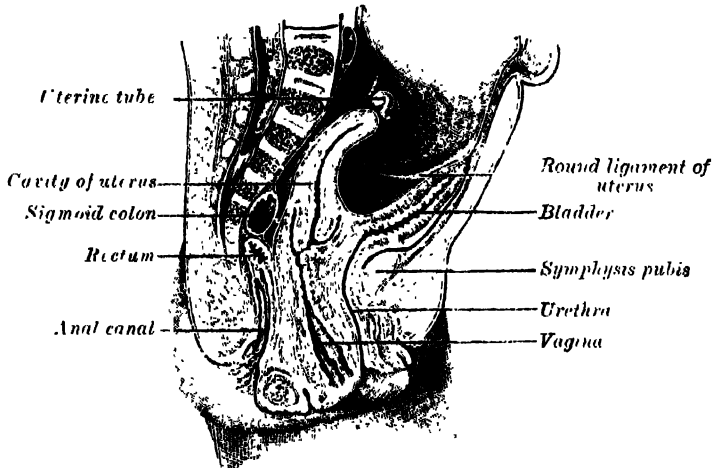
The total length of the uterine cavity from the external orifice to the fundus is about 6 cm.

Ligaments.—The ligaments of the uterus are eight in number; an anterior; a posterior; two lateral or broad; two uterosacral; and two round ligaments.

The *anterior ligament* consists of the vesico-uterine fold of peritoneum, which is reflected on to the bladder from the front of the uterus, at the junction of the cervix and body.

The *posterior ligament* consists of the rectovaginal fold of peritoneum, which is reflected from the back of the posterior fornix of the vagina on to the front of the rectum. It forms the bottom of a deep pouch called the *recto-uterine excavation* (pouch of Douglas), which is bounded in front by the

FIG. 1097.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine which intervened between the uterus and the bladder have been removed.



posterior wall of the uterus, the supravaginal cervix, and the posterior fornix of the vagina; behind, by the rectum; and laterally by two crescentic folds of peritoneum which pass backwards from the cervix uteri on either side of the rectum to the posterior wall of the pelvis. These folds are named the *sacro-genital*, or *recto-uterine*, folds. They contain a considerable amount of fibrous tissue and non-striped muscular fibres which are attached to the front of the sacrum and constitute the *uterosacral ligaments*.

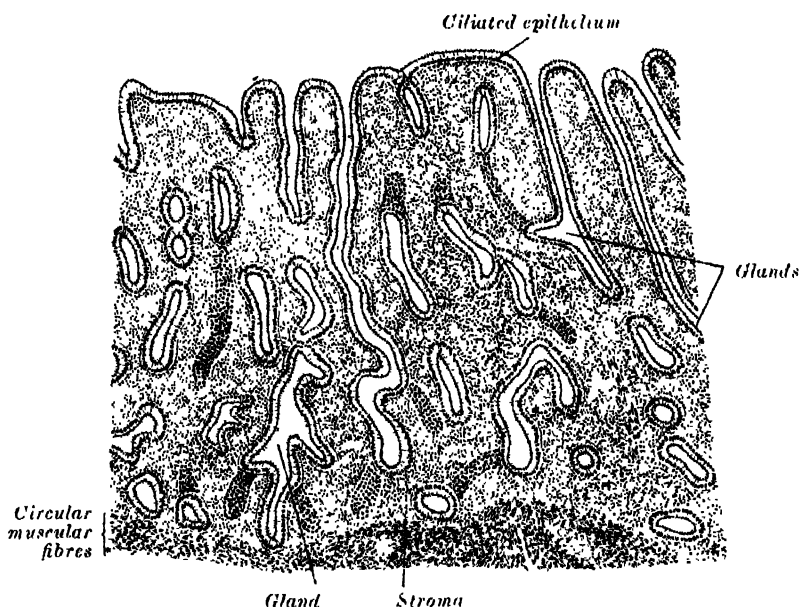
The *two lateral or broad ligaments* pass from the sides of the uterus to the lateral walls of the pelvis. Together with the uterus they form a septum across the female pelvis, dividing that cavity into two portions. The anterior part contains the bladder; the posterior part, the rectum, and in certain conditions some coils of the small intestine. Between the two layers of each broad ligament are: (1) the uterine tube; (2) the round ligament of the uterus; (3) the ovary and its ligament; (4) the epoöphoron and paroöphoron; (5) connective tissue; (6) unstriped muscular fibres; and (7) blood-vessels and nerves. The portion of the broad ligament which stretches from the uterine tube to the level of the ovary is named the *mesosalpinx*. Between the fimbriated extremity of the uterine tube and the lower attachment of the broad ligament is a concave rounded margin, called the *infundibulopelvic ligament*.

The *round ligaments* are two flattened bands between 10 cm. and 12 cm. in length, situated between the layers of the broad ligament in front of and below the uterine tubes. Commencing on either side at the lateral angle of

the uterus, each ligament is directed forwards, upwards, and lateralwards over the external iliac vessels. It then passes through the abdominal inguinal ring and along the inguinal canal to the labium majus, in which it is lost. The round ligaments consist principally of muscular tissue prolonged from the uterus; also of some fibrous and areolar tissue, besides blood-vessels, lymphatics, and nerves, enclosed in a duplicature of peritoneum, which, in the foetus, is prolonged in the form of a tubular process (canal of Nuck) for a short distance into the inguinal canal. The canal of Nuck is generally obliterated in the adult, but sometimes remains pervious even in advanced life. It is analogous to the saccus vaginalis which precedes the descent of the testis.

In addition to the ligaments just described, there is a band named the *ligamentum transversale colli* (Mackenrodt) on either side of the cervix uteri. It is attached to the side of the cervix uteri and to the vault and lateral fornix of the vagina, and is continuous externally with the fibrous tissue which surrounds the pelvic blood-vessels.

FIG. 1098.-A vertical section through the mucous membrane of a human uterus.
(Sobotta.)



The form, size, and situation of the uterus vary at different periods of life and under different circumstances.

In the *foetus* the uterus is contained in the abdominal cavity, projecting beyond the superior aperture of the pelvis (fig. 1097). The cervix is considerably larger than the body.

At *puberty* the uterus is pyriform in shape, and weighs from 14 to 17 grs. The fundus is just below the level of the superior aperture of the pelvis. The palmate folds are distinct, and extend to the upper part of the cavity.

The position of the uterus in the *adult* is liable to considerable variation, depending chiefly on the condition of the bladder and rectum. When the bladder is empty the entire uterus is directed forwards, and is at the same time bent on itself at the junction of the body and cervix, so that the body lies upon the bladder. As the latter fills, the uterus gradually becomes more and more erect, until with a fully distended bladder the fundus may be directed backwards towards the sacrum.

During *menstruation* the organ is enlarged, and more vascular, and its surfaces are rounder; the external orifice is rounded, its labia swollen, and the lining membrane of the body is thicker, softer, and of a darker colour.

During *pregnancy* the uterus becomes enormously enlarged, and in the eighth month reaches the epigastric region. The increase in size is partly due to growth of pre-existing muscle, and partly to development of new fibres.

After *parturition* the uterus nearly regains its usual size, weighing about 42 gr.; but its cavity is larger than in the virgin state, its vessels are tortuous, and its muscular

layers are more defined; the external orifice is more marked, and its edges present one or more fissures.

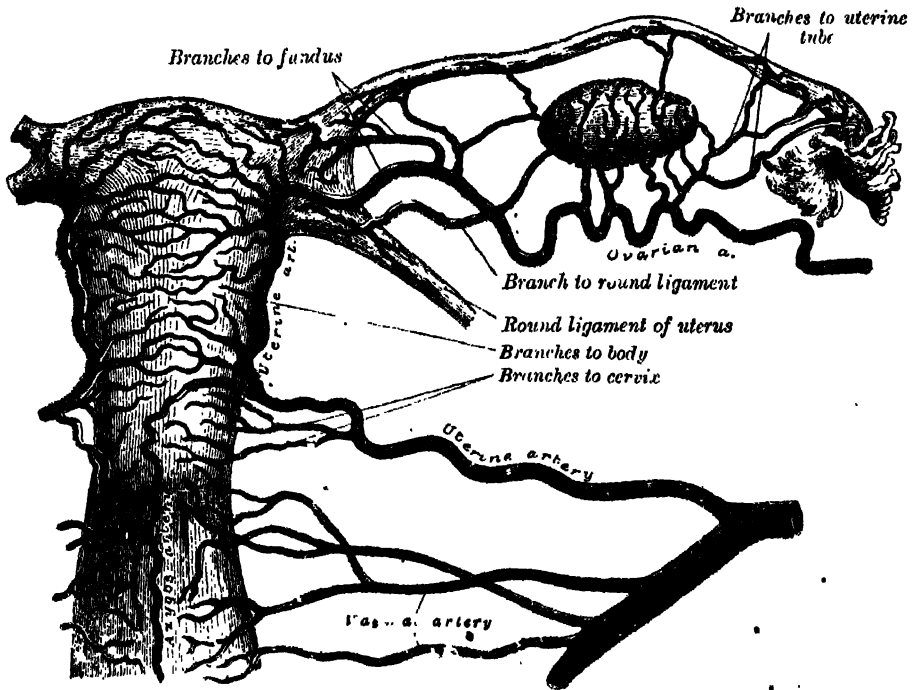
In old age the uterus becomes atrophied, and paler, and denser in texture; a more distinct constriction separates the body and cervix. The internal orifice is frequently, and the external orifice occasionally, obliterated, while the lips almost entirely disappear.

Structure.—The uterus is composed of three coats: an external or serous, a middle or muscular, and an internal or mucous.

The *serous coat* is derived from the peritoneum; it invests the fundus and the whole of the intestinal surface of the uterus; but covers the vesical surface only as far as the junction of the body and cervix. In the lower fourth of the intestinal surface the peritoneum is not closely connected with the uterus, being separated from it by a layer of loose cellular tissue and some large veins.

The *muscular coat* forms the chief bulk of the substance of the uterus. In the virgin it is dense, firm, of a greyish colour, and cuts almost like cartilage. It is thick opposite

FIG. 1099.—The arteries of the internal organs of generation of the female, seen from behind. (After Hyrtl.)



the middle of the body and fundus, and thin at the orifices of the uterine tubes. It consists of bundles of unstripped muscular fibres, disposed in layers, intermixed with areolar tissue, blood-vessels, lymphatic vessels, and nerves. The layers are three in number: external, middle and internal. The external and middle layers constitute the muscular coat proper, while the internal layer is a greatly hypertrophied *muscularis mucosæ*. During pregnancy the muscular tissue becomes more prominently developed, the fibres being greatly enlarged.

The external layer, placed beneath the peritoneum, is disposed as a thin plane on the vesical and intestinal surfaces. It consists of fibres which pass transversely across the fundus, and, converging at each lateral angle of the uterus, are continued on to the uterine tube, the round ligament, and the ligament of the ovary: some passing at each side into the broad ligament, and others running backwards from the cervix into the sacro-uterine ligaments. The middle layer of fibres presents no regularity in its arrangement, being disposed longitudinally, obliquely, and transversely. It contains many blood-vessels. The internal layer consists of circular fibres arranged in the form of two hollow cones, the apices of which surround the orifices of the uterine tubes, their bases intermingling with one another on the middle of the body of the uterus. At the internal orifice these circular fibres form a distinct sphincter. The internal muscular layer is separated from the muscular coat proper by a number of large blood-vessels lying in what represents a submucous coat.

The *mucous membrane* (fig. 1098) is smooth, and closely adherent to the subjacent tissue. It is continuous, through the fimbriated extremities of the uterine tubes, with the peritoneum; and, through the external uterine orifice, with the lining of the vagina.

In the body of the uterus the mucous membrane is smooth, soft, of a pale red colour, lined by columnar ciliated epithelium, and presents, when viewed with a lens, the orifices of numerous tubular follicles, arranged perpendicularly to the surface. The structure of the corium differs from that of ordinary mucous membranes, and consists of an embryonic nucleated and highly cellular form of connective tissue in which run numerous large lymphatics. In it are the tube-like uterine glands, lined by ciliated columnar epithelium. They are of small size in the unimpregnated uterus, but shortly after impregnation become enlarged and elongated, presenting a contorted or wavy appearance.

In the cervix the mucous membrane is sharply differentiated from that of the uterine cavity. It is thrown into numerous oblique ridges, which diverge from an anterior and posterior longitudinal raphe. In the upper two-thirds of the canal, the mucous membrane is provided with numerous deep glandular follicles which secrete a clear viscid alkaline mucus; and, in addition, extending through the whole length of the canal is a variable number of little cysts, presumably follicles which have become occluded and distended with retained secretion. They are called the *agula Nabothi*. The mucous membrane covering the lower half of the cervical canal presents numerous papillae. The epithelium of the upper two-thirds is cylindrical and ciliated, but below this it loses its cilia, and, close to the external orifice, changes to stratified squamous epithelium. On the vaginal surface of the cervix the epithelium is similar to that lining the vagina, viz. stratified squamous.

Vessels and Nerves.—The arteries of the uterus are the uterine, from the hypogastric; and the ovarian, from the abdominal aorta (fig. 1099). They are remarkable for their tortuous course in the substance of the organ, and for their frequent anastomoses. The termination of the ovarian artery meets that of the uterine artery, and forms an anastomotic trunk from which branches are given off to supply the uterus, their disposition being circular. The veins are of large size, and correspond with the arteries. They end in the uterine plexuses. In the impregnated uterus the arteries carry the blood to, and the veins convey it away from, the intervillous space of the placenta (p. 62). The lymphatics are described on p. 735. The nerves are derived from the hypogastric and ovarian plexuses, and from the third and fourth sacral nerves.

Applied Anatomy.—A certain amount of anteversion or retroversion of the uterus can take place without the conditions being regarded as pathological, but when the degree of flexion at the junction of the body with the cervix becomes considerable it must be regarded as a morbid condition. This is especially true of retroversion combined with retroflexion. Retroversion alone is a falling back of the whole uterus, so that the cervix points upwards towards the os pubis; retroflexion is a bending backwards of the body, the cervix remaining in its normal position. The two conditions are usually combined. Prolapse of the uterus is another common infirmity. The organ sinks to an abnormally low level in the pelvis, and sometimes protrudes beyond the vulva. This is due to the supporting mechanism of the uterus being insufficient to sustain the strain thrown upon it.

The uterus may require removal in cases of malignant disease or for fibroid tumours. Carcinoma is the most common form of malignant disease of the uterus. It may show itself either as a columnar carcinoma or as a squamous carcinoma; the former commencing either in the cervix or body of the uterus; the latter always commencing in the epithelial cells of the mucous covering of the vaginal surface of the cervix. Cancer of the body or of the cervix may be treated in the early stage, before fixation has taken place, by removal of the uterus, either through the vagina or by means of abdominal section, but if the body be much enlarged the former operation is impossible. Vaginal hysterectomy is now rarely performed.

In the treatment of uterine fibroids which require operative interference, removal of the whole body of the uterus, together with the tumours, with or without the cervix, through an abdominal incision, gives the most satisfactory results. After the abdomen has been opened the ovarian vessels are secured (one ovary at least being left, provided it be healthy) and the broad ligaments are divided. It will now be found that the uterus can be raised out of the pelvis, and a transverse incision is made through the peritoneum, where it is reflected from the front of the uterus on to the back of the bladder, and this viscus is separated from the surface of the uterus. The uterus is now turned forwards and the peritoneum of the recto-uterine excavation incised transversely. The uterus is now almost free, and is held only by the lower part of the broad ligament on either side, containing the uterine artery. A ligature is made to encircle this as close to the uterus as possible, the position of the ureter being always kept in mind, and, after having been tied, the structures are divided between the ligature and the uterus. The body of the uterus can now be removed by cutting it across at its junction with the cervix, or if desired the vaginal wall can be incised both front and back and the cervix removed together with the body. The peritoneum is finally sewn up carefully across the floor of the pelvis, with a transverse line of suture from one uterine tube to the other, so as to leave no raw surface to which small intestine can adhere.

Inflammation of the cellular tissue surrounding the cervix occasionally takes place. Laceration of the cervix by instruments or by the foetal head frequently occurs, opening up the cellular planes and so exposing them to any infection that may be present. An inflammatory mass forms in the cellular tissue between the layers of the broad ligament

or of the uterosacral ligaments, and the condition is termed *pelvic cellulitis*, or *parametritis*. This condition is usually confined to one side of the pelvis, forming a large inflammatory mass which pushes the uterus over to the opposite side. It does not always remain localised, however, but may spread widely, surrounding the rectum or the neck of the bladder, or mounting into the iliac fossa, or even to the perinephric cellular tissue. The condition may resolve or an abscess may form. In the former condition the cicatrization of the inflammatory products produces displacements of the uterus towards the affected side of the pelvis, or may result in stricture of the rectum when that viscus has been surrounded by the process. When suppuration ensues, the pus may burst into the bladder, vagina, or rectum, or it may present above the inguinal ligament, or it may mount to the anterior abdominal wall in front of the bladder or to the posterior abdominal wall between the iliac crest and last rib. The abscess may, moreover, make its way into the buttock by passing out of the pelvis through the greater sciatic foramen, or it may pass down between the fibres of the Levator ani and appear as a secondary ischiorectal abscess.

THE VAGINA (fig. 1095)

The **vagina** extends from the vestibule to the uterus, and is situated behind the bladder and in front of the rectum; it is directed upwards and backwards, its axis forming with that of the uterus an angle of over ninety degrees, opening forwards. Its walls are ordinarily in contact, and the usual shape of its lower part on transverse section is that of an H, the transverse limb being slightly curved forwards or backwards, while the lateral limbs are somewhat convex towards the median line; its middle part has the appearance of a transverse slit. Its length is 6 cm. to 7.5 cm. along its anterior wall, and 9 cm. along its posterior wall. It is constricted at its commencement, dilated in the middle, and narrowed near its uterine extremity; it surrounds the vaginal portion of the cervix uteri, a short distance from the external orifice of the uterus, its attachment extending higher up on the posterior than on the anterior wall of the uterus. To the recess behind the cervix the term *posterior fornix* is applied, while the smaller recesses in front and at the sides are called the *anterior* and *lateral fornices*.

The *anterior wall* of the vagina is in relation with the fundus of the bladder, and with the urethra. Its *posterior wall* is separated from the rectum by the recto-uterine excavation in its upper fourth, and by the rectovesical fascia in its middle two-fourths; the lower fourth is separated from the anal canal by the perineal body. Its sides are enclosed between the Levatores ani muscles. As the terminal portions of the ureters pass forwards and medialwards to reach the fundus of the bladder, they run close to the lateral fornices of the vagina, and as they enter the bladder are slightly in front of the anterior fornix.

Structure.—The vagina consists of an internal mucous lining and a muscular coat, separated by a layer of erectile tissue.

The *mucous membrane* is continuous above with that lining the uterus. Its inner surface presents two longitudinal ridges, one on its anterior and the other on its posterior wall. These ridges are called the *columns of the vagina*, and from them numerous transverse ridges or rugæ extend outwards on either side. These rugæ are divided by furrows of variable depth, giving to the mucous membrane the appearance of being studded over with conical projections or papillæ; they are most numerous near the orifice of the vagina, especially before parturition. The epithelium of the mucous membrane is of the stratified squamous variety. The mucous coat contains a number of mucous crypts, but no true glands.

The *muscular coat* consists of two layers: an external longitudinal, which is by far the stronger, and an internal circular layer. The longitudinal fibres are continuous with the superficial muscular fibres of the uterus. The strongest fasciculi are those attached to the rectovesical fascia on either side. The two layers are not distinctly separable from each other, but are connected by oblique decussating fasciculi, which pass from the one layer to the other. In addition to this, the lower end of the vagina is surrounded by a band of striped muscular fibres, the *Sphincter vaginae* (p. 476).

External to the muscular coat is a layer of connective tissue, containing a large plexus of blood-vessels.

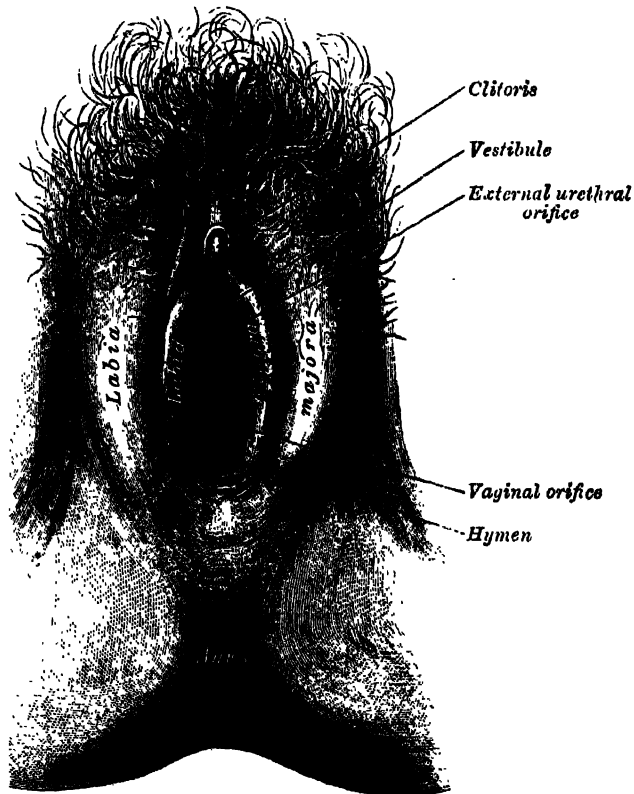
The *erectile tissue* is situated between the mucous membrane and the muscular coat; it consists of a layer of loose connective tissue, imbedded in which is a plexus of large veins, and numerous bundles of unstriped muscular fibres, derived from the circular muscular layer. The arrangement of the veins is similar to that found in other erectile tissues.

EXTERNAL ORGANS (fig. 1100)

The external genital organs of the female are: the mons pubis, the labia majora et minora pudendi, the clitoris, the vestibule of the vagina, the bulb of the vestibule, and the greater vestibular glands. The term *pudendum* or *vulva*, as generally applied, includes all these parts.

The mons pubis (mons Veneris), the rounded eminence in front of the pubic symphysis, is formed by a collection of fatty tissue beneath the skin. It becomes covered with hair at the time of puberty.

FIG. 1100.—The external genital organs of the female. The labia have been drawn apart.



The labia majora are two prominent longitudinal cutaneous folds which extend downwards and backwards from the mons pubis, and form the lateral boundaries of a fissure or cleft, the *pudendal cleft* or *rima*, into which the vagina and urethra open. Each labium has two surfaces, an outer, pigmented and covered with crisp hairs; and an inner, smooth and beset with large sebaceous follicles. Between the two surfaces there is a considerable quantity of areolar tissue, fat, and a tissue resembling the dartos tunic of the scrotum, besides vessels, nerves, and glands. The labia are thicker in front, where they form by their meeting the *anterior labial commissure*. Posteriorly they are not really joined, but appear to become lost in the neighbouring integument, ending close to, and nearly parallel with, each other. Together with the connecting skin between them, they form the *posterior labial commissure*, or posterior boundary of the pudendum. The interval between the posterior commissure and the anus, from 2.5 cm. to 3 cm. in length, constitutes the *gynaecological perinaeum*.

The labia minora are two small cutaneous folds, situated between the labia majora, and extending from the clitoris obliquely downwards, lateralwards, and backwards for about 4 cm. on either side of the orifice of the vagina,

between which and the labia majora they end; in the virgin the posterior ends of the labia minora are usually joined across the middle line by a fold of skin, named the *frenulum of the labia*, or *fourchette*. Anteriorly, each labium minus divides into two portions: the upper division passes above the clitoris to meet its fellow of the opposite side, forming a fold which overhangs the glans clitoridis, and is named the *præputium clitoridis*; the lower division passes beneath the clitoris and is united to its under surface, forming, with its fellow of the opposite side, the *frenulum of the clitoris*. On the opposed surfaces of the labia minora are numerous sebaceous follicles.

The vestibule.—The cleft between the labia minora is named the *vestibule of the vagina*: in it are the urethral and vaginal orifices and the openings of the ducts of the greater vestibular glands. The part of the vestibule between the vaginal orifice and the frenulum of the labia consists of a shallow depression named the *navicular fossa*.

The clitoris is an erectile structure, homologous with the penis. It is situated beneath the anterior labial commissure, partially hidden between the anterior ends of the labia minora. It consists of two corpora cavernosa, composed of erectile tissue enclosed in a dense layer of fibrous membrane, united together along their medial surfaces by an incomplete fibrous pectiniform septum; each corpus cavernosum is connected to the pubic and ischial rami by a crus. The free extremity, or *glans clitoridis*, is a small rounded tubercle, consisting of spongy erectile tissue, and highly sensitive. The clitoris is provided, like the penis, with a suspensory ligament, and with two small muscles, the Ischio-cavernosi, which are inserted into the crura of the clitoris.

The external urethral orifice is placed about 2.5 cm. behind the glans clitoridis and immediately in front of the orifice of the vagina: it usually assumes the form of a short, sagittal cleft with slightly raised margins.

The vaginal orifice is a median slit below and behind the opening of the urethra; its size varies inversely with that of the hymen.

The hymen is a thin fold of mucous membrane situated at the orifice of the vagina; the inner surfaces of the fold are normally in contact with each other, and the vaginal orifice appears as a cleft between them. The hymen varies much in shape. When stretched, its commonest form is that of a ring, generally broadest posteriorly; sometimes it is represented by a semilunar fold, with its concave margin turned towards the pubes. Occasionally it is cribriform, or its free margin forms a membranous fringe. It may be entirely absent, or may form a complete septum across the lower end of the vagina; the latter condition is known as an imperforate hymen. When the hymen has been ruptured, small rounded elevations known as the *caruncule hymenales* are found as its remains.

The bulb of the vestibule is the homologue of the urethral bulb and adjoining part of the corpus cavernosum urethræ of the male, and consists of two elongated masses of erectile tissue, placed one on either side of the vaginal orifice and united to each other in front by a narrow median band termed the *pars intermedia*. Each lateral mass measures about 3 cm. in length. Their posterior ends are expanded and are in contact with the greater vestibular glands; their anterior ends are tapered and joined to one another by the pars intermedia; their deep surfaces are in contact with the inferior fascia of the urogenital diaphragm; superficially they are covered by the Bulbocavernosus.

The greater vestibular glands (glands of Bartholin) are the homologues of the bulbo-urethral glands in the male. They consist of two small, round or oval bodies of a reddish-yellow colour, situated one on either side of the vaginal orifice, in contact with the posterior end of each lateral mass of the bulb of the vestibule. Each gland opens by means of a duct, about 2 cm. long, immediately laterally to the hymen, in the groove between its attached border and the labium minus.

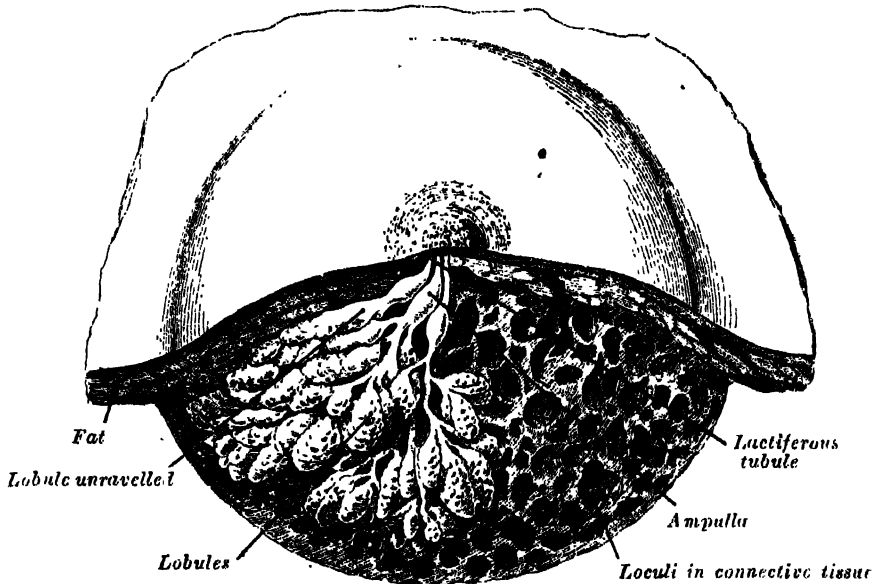
THE MAMMÆ

The mammae or breasts secrete the milk, and are accessory glands of the generative system. They exist in the male as well as in the female, but in the former only in the rudimentary state. In the female they are two large hemispherical eminences lying within the superficial fascia on the front and

sides of the chest; each extends from the second rib above to the sixth rib below, and from the side of the sternum to near the mid-axillary line. In weight and size they differ at different periods of life, and in different individuals. Before puberty they are small, but they enlarge as the generative organs become more completely developed. They increase during pregnancy, and especially after delivery, and become atrophied in old age. The left mamma is generally a little larger than the right. The deep surface of each is nearly circular, flattened, or slightly concave, and has its long diameter directed upwards and lateralwards towards the axilla; it is separated from the fascia covering the Pectoralis major, Serratus anterior, and Obliquus externus abdominis by loose connective tissue. The subcutaneous surface of the mamma is convex, and presents, just below the centre, a small conical prominence, the papilla.

The **mammary papilla** or **nipple** is a cylindrical or conical eminence situated about the level of the fourth intercostal space. It is capable of

FIG. 1101.—A dissection of the lower half of the mamma during the period of lactation. (Luschka.)

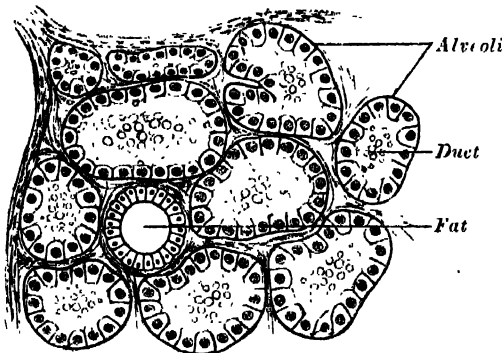


undergoing a sort of erection from mechanical excitement, a change mainly due to the contraction of its muscular fibres. It is of a pink or brownish hue, its surface wrinkled and provided with secondary papillæ; and it is perforated by from fifteen to twenty orifices, the apertures of the lactiferous ducts. The base of the mammary papilla is surrounded by an *areola*. In the virgin the areola is of a delicate rosy hue; about the second month after impregnation it enlarges and acquires a darker tinge, and as pregnancy advances it may assume a dark brown, or even black colour. This colour diminishes as soon as lactation is over, but is never entirely lost. These changes in the colour of the areola are of importance in forming a conclusion in a case of suspected first pregnancy. Near the base of the papilla, and upon the surface of the areola, are numerous large sebaceous glands, the *areolar glands*, which become much enlarged during lactation, and present the appearance of small tubercles beneath the skin; they secrete a peculiar fatty substance, which serves as a protection to the integument of the papilla during the act of sucking. The mammary papilla consists of numerous vessels, intermixed with plain muscular fibres, which are principally arranged in a circular manner around the base, but a few fibres radiate from base to apex.

Structure (figs. 1101, 1102).—The mamma consists (a) of gland-tissue; (b) of fibrous tissue, connecting its lobes; and (c) of fatty tissue in the intervals between the lobes.

The subcutaneous tissue of the mamma presents numerous irregular processes which project towards the skin, and are joined to it by bands of connective tissue. The gland-tissue, when freed from fibrous tissue and fat, is of a pale reddish colour, firm in texture, flattened from before backwards and thicker in the centre than at the circumference. It consists of numerous lobes, and these are composed of lobules, connected together by areolar tissue, blood-vessels, and ducts. The smallest lobules consist of a cluster of rounded alveoli which open into the smallest branches of the lactiferous ducts; these ducts unite to form larger ducts, and these end in single canals, corresponding with each of the chief subdivisions of the gland. The number of excretory ducts varies from fifteen to twenty; they are termed the *tubuli lactiferi*. They converge towards the areola, beneath which they form dilatations, or *ampullæ*, which serve as reservoirs for the milk. At the base of the papilla they become contracted, and pursue a straight course to its summit, perforating it by separate orifices considerably narrower than the ducts themselves. The ducts are composed of areolar tissue containing longitudinal and transverse elastic fibres; they are lined by columnar epithelium resting on a basement membrane. The epithelium of the mamma differs according to the state of activity of the organ. In the gland of a woman who is not pregnant or suckling, the alveoli are very small and solid,

FIG. 1102.—A section through a portion of the mamma.



being filled with a mass of granular polyhedral cells. During pregnancy the alveoli enlarge, and the cells undergo rapid multiplication. At the commencement of lactation, the cells in the centre of the alveolus undergo fatty degeneration, and are eliminated in the first milk, as *colostrum corpuscles*. The peripheral cells of the alveolus remain, and form a single layer of granular, short columnar cells, with spherical nuclei, lining the basement membrane. When the gland is active, oil globules are found in the alveolar cells and are discharged into the lumen, constituting the milk-globules. When the acini are distended by the accumulation of the secretion the lining epithelium becomes flattened.

The fibrous tissue invests the entire surface of the mamma, and sends down septa between its lobes, connecting them together.

The fatty tissue covers the surface of the gland, and occupies the interval between its lobes. It usually exists in considerable abundance, and determines the form and size of the gland. There is no fat immediately beneath the areola and papilla.

Vessels and Nerves.—The arteries supplying the mamma are derived from the thoracic branches of the axillary, the intercostals, and the internal mammary. The veins describe an anastomotic circle round the base of the papilla, called by Haller the *circulus venosus*. From this, large branches transmit the blood to the circumference of the gland, and end in the axillary and internal mammary veins. The lymphatics are described on p. 788. The nerves are derived from the anterior and lateral cutaneous branches of the fourth, fifth, and sixth thoracic nerves.

Applied Anatomy.—The ducts descending from the mammary papilla radiate through the gland, and when an incision is made into the breast the scalpel should be directed radially, from the centre to the periphery, so that it may not pass across the ducts. A milk duct may become obstructed and distended, forming a tumour known as a *galactocoele*. Abscess frequently occurs about the mamma, more often in women who are lactating, especially in those who have cracks or fissures about the papilla. The abscess may be between the septa, in the gland-tissue itself, or it may lie beneath the skin by the side of the papilla and superficial to the mamma, or it may form beneath the mamma, between it and the deep fascia. Free incision, radiating from the papilla, is required in such cases.

Cystic formation of many different kinds is commonly seen in the mamma; in some cases it is due to dilatation of the larger ducts or of the lymph-spaces throughout the gland; in others the cysts occur in new growths of the mamma, or as the result of obstruction of the smaller ducts by chronic inflammatory processes.

Malignant growths are seen more often in the mamma than in any other organ; they are of great variety, but the commonest is the spheroidal-celled cancer, the cells of which are intermingled with a varying amount of fibrous tissue. A hard contracting tumour-mass results, which drags on the fibrous septa between the lobes so that fixation or retraction of the papilla ensues, and sooner or later the malignant infiltration invades the surrounding gland-tissues, the skin, the deep fascia and Pectorales, and even the chest-wall and pleura. The lymph-glands beneath the Pectorales and those situated towards the apex of the axilla become early involved with secondary malignant deposit, and later

the supraclavicular glands enlarge. In other cases the mediastinal glands may be involved, when the disease is situated on the medial side of the papilla.

The operation for removal of a mamma affected with malignant disease should be an extensive procedure, with the object of extirpating all fascial planes and lymphatic structures that may become infected. The incision commences below, over the upper part of the sheath of the Rectus, encloses the mamma by an ellipse, and is then continued on towards the apex of the axilla. The skin is reflected on both sides of the incision; anteriorly, till the sternum is reached, and posteriorly to the posterior boundary of the axilla. The origin of the sternal portion of the Pectoralis major is then divided and turned outwards. The Pectoralis minor is next seen, and its origin is then divided in a similar manner. The whole of the muscular and fascial planes of the front of the chest are thus separated *en masse*, carrying with them the mamma and the skin covering it. The insertions of the two Pectorales have next to be divided, and finally the axillary lymph-glands and fat are removed from the axillary vessels in one piece with the mass of tissue already detached. This is done by first freely exposing the whole length of the axillary vein and then, with a blunt instrument, peeling the structures off the vein from above downwards, from the point where they are crossed by the Subclavius muscle to the lower border of the axilla. In this part of the operation many branches of both vein and artery require ligature. The only thing which then remains to be divided is the deep fascia along the posterior axillary wall. The wound is then closed, drainage is provided, and firm pressure is applied with the dressings. It will be noted that the clavicular portion of the Pectoralis major is left intact, as it is of considerable service for the subsequent movements of the arm, the utility of which is but slightly impaired.

THE DUCTLESS GLANDS

The ductless glands are secreting structures which do not possess ducts through which their secretions may be discharged. The materials which they elaborate are termed *internal secretions*, and are conveyed into the blood by the veins or by the lymphatics.

The ductless glands consist of (a) the thyroid, parathyroids, thymus, spleen, suprarenal glands, glomera carotica, and glomus coccygeum (which will be described in this section); (b) the lymph-glands (described in the section on Angiology); and (c) the pineal gland and hypophysis cerebri (described in the section on Neurology).

THE THYROID GLAND (fig. 1103)

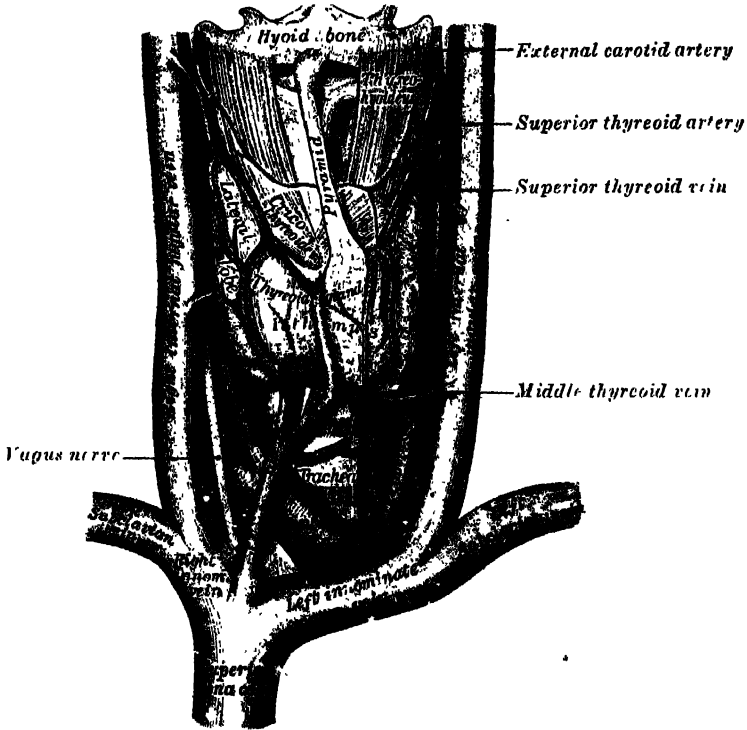
The thyroid gland is a highly vascular organ, situated at the front and sides of the lower part of the neck, opposite the fifth, sixth and seventh cervical vertebrae. It is ensheathed by the pretracheal layer of the fascia colli, and consists of right and left lobes connected across the middle line by a narrow portion, the *isthmus*. Its weight is somewhat variable, but is usually about 30 gm. It is slightly heavier in the female, in whom it becomes enlarged during menstruation and pregnancy.

The lobes are conical in shape, the apex of each being directed upwards and laterally as far as the junction of the middle with the lower third of the thyroid cartilage; the base looks downwards, and is on a level with the fifth or sixth tracheal ring. Each lobe is about 5 cm. long; its greatest width is about 3 cm., and its thickness about 2 cm. The lateral or superficial surface is convex, and covered by the skin, the superficial and deep fascia, the Sternocleidomastoideus, the superior belly of the Omohyoideus, the Sternohyoideus and Sternothyroideus, and beneath the last muscle by the pretracheal layer of the deep fascia, which forms a capsule for the gland. The medial surface is moulded over the thyroid and cricoid cartilages, the trachea, the Constrictor pharyngis inferior and posterior part of the Cricothyroideus, the oesophagus (particularly on the left side of the neck), the superior and inferior thyroid arteries, and the recurrent nerves. The posterior surface overlaps the common carotid artery, and, as a rule, the parathyroids. The anterior border is thin, and inclines obliquely from above downwards towards the middle line of the neck.

The *isthmus* connects together the lower thirds of the lobes ; it measures about 1.25 cm. transversely, and the same vertically, and usually covers the second and third rings of the trachea. Its situation and size present, however, many variations. It is covered by the skin and fascia, and close to the middle line, on either side, by the *Sternothyroideus*. Across its upper border runs an anastomotic branch uniting the two superior thyroid arteries ; at its lower border are the inferior thyroid veins. Sometimes the isthmus is altogether wanting.

A third lobe, of conical shape, called the *pyramidal lobe*, frequently arises from the upper part of the isthmus, or from the adjacent portion of either

FIG. 1103.--The thyroid gland and its relations.



lobe, but most commonly the left, and ascends as far as the hyoid bone. It is occasionally quite detached, or may be divided into two or more parts.

A fibrous or muscular band is sometimes found attached, above, to the body of the hyoid bone, and below, to the isthmus of the gland, or its pyramidal lobe ; when muscular, it is termed the *Levator glandulae thyroideae*.

Small detached portions of thyroid tissue are sometimes found in the vicinity of the lateral lobes or above the isthmus ; they are called *accessory thyroid glands*.

Structure.—The thyroid gland is closely invested by a thin capsule of connective tissue, which sends incomplete septa into its substance, dividing it into masses of irregular form and size. The gland is of a brownish-red colour, and is made up of a number of closed vesicles, just visible with the naked eye, containing a yellow glairy fluid, and separated from each other by intermediate connective tissue (fig. 1104).

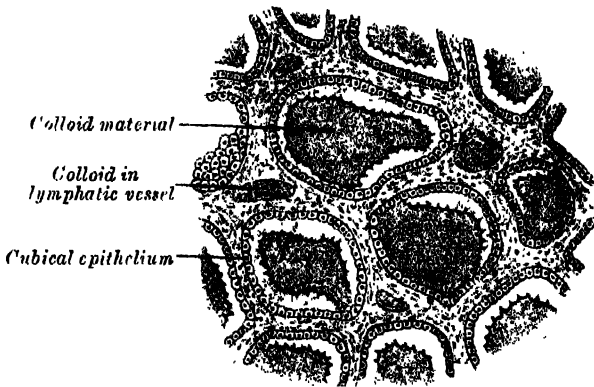
The vesicles of the thyroid of the adult animal are generally closed spherical sacs ; but in some young animals (e.g. dogs) they are more or less tubular and branched. Each is lined by a single layer of cubical epithelium. There does not appear to be a basement membrane, so that the epithelial cells are in direct contact with the connective tissue reticulum which supports the acini. The vesicles are of various sizes, and contain a viscid, homogeneous, semi-fluid, slightly yellowish, colloidal material ; red corpuscles are found in it in various stages of disintegration and decolorisation, the yellow tinge being probably due to hæmoglobin, which is set free from the coloured corpuscles. The colloid

material contains an iodine compound, *iodothylin*, and, when coagulated by hardening reagents, is readily stained by eosin and other dyes. It passes out between the cubical cells and is absorbed into the blood or lymph.

Vessels and Nerves.—The *arteries* supplying the thyroid gland are the superior and inferior thyroid arteries and sometimes an additional branch (*a. thyroidea ima*) from the innominate artery or the arch of the aorta, which ascends upon the front of the trachea. The arteries are remarkable for their large size and frequent anastomoses. The *veins* form a plexus on the surface of the gland and on the front of the trachea; from this plexus the superior, middle, and inferior thyroid veins arise; the superior and middle end in the internal jugular vein, the inferior in the innominate vein. The capillary blood-vessels form a dense plexus in the connective tissue around the vesicles, between the epithelium of the vesicles and the endothelium of the lymphatics which surround a greater or smaller part of the circumference of the vesicle. The *lymphatic vessels* run in the interlobular connective tissue, not uncommonly surrounding the arteries which they accompany, and communicate with a network in the capsule of the gland; they may contain colloid material. They end in the thoracic duct and the right lymphatic trunk. The *nerves* are derived from the middle and inferior cervical ganglia of the sympathetic.

Applied Anatomy.—An enlargement of the thyroid gland is called a *goitre*. The swelling may take the form of a diffuse hypertrophy of the whole gland, giving rise to the *parenchymatous goitre*, this being mainly due to the hypertrophy of the thyroid follicles

FIG. 1104.—A section through the thyroid gland of a sheep. $\times 100$.



themselves; in other cases a *fibroid* form of goitre is produced owing to the increase in the interstitial connective tissue; in others, again, the vascular changes may preponderate, and many large pulsating vessels may be present. Much more commonly, however, the enlargement is due to adenomatous new growth in the substance of the thyroid; these tumours are usually innocent, and tend to destroy life only by pressure on the air-passages. A single tumour is the rule, but in some instances a very large number may be present. They tend to show marked mucoid degeneration, and so become converted into cystadenomata, and finally into what appear to be simple cysts. These tumours may attain an enormous size and may involve practically the whole gland. Malignant tumour-growth more rarely attacks the organ.

When a goitre continues to grow, and especially when there are commencing symptoms of tracheal pressure, operative interference becomes necessary. This is not difficult, if an encapsulated tumour is to be dealt with, provided the anatomical layers covering it are remembered. In such a case it is necessary to make an incision suited to the size and situation of the tumour, and having divided the deep cervical fascia, to retract the Sternocleidomastoideus or divide it if necessary. The Sternohyoideus and Sternothyroideus next require division, or in some cases their fibres may be separated and drawn asunder, and beneath is found the ensheathing capsule derived from the pre-tracheal fascia; this requires division, and exposes the true capsule of the thyroid gland. In the case of an adenoma or cyst, this true capsule then needs incision before the tumour can be effectually shelled out, and this is usually accomplished with very little hæmorrhage, and without any of the main vessels of the gland requiring ligature.

Partial extirpation of the thyroid, viz. the removal of one lateral lobe with division of the isthmus, may be required in cases of parenchymatous goitre, and in the diffuse form of adenomatous disease. It is a more radical proceeding, and carries with it a much greater risk from hæmorrhage; there is also a danger of wounding the recurrent nerve. The whole gland must never be removed, as such a procedure is followed by the development of myxædema. In hemithyroidectomy a free incision is indicated—dividing

muscles, if necessary—to expose the true gland capsule, but at the same time avoiding injury to the large vessels which lie beneath it. The superior and inferior pedicles containing the respective thyroid arteries are then isolated and clamped on either side and divided between the clamps. The half gland is then turned over towards the middle line, and the isthmus ligatured and divided. Some venous bleeding is apt to occur from connexions with the tracheal veins, and must be stopped. The pedicles are then securely ligatured and the wound closed. In dealing with the inferior thyroid artery, the position of the recurrent nerve must be borne in mind, so as not to ligature or divide it. Temporary aphonia not uncommonly follows from bruising of the nerve, and if nothing more serious has occurred soon passes off.

THE PARATHYROID GLANDS

The parathyroid glands are small brownish-red bodies, situated as a rule between the posterior borders of the lateral lobes of the thyroid gland and its capsule. They measure on an average about 6 mm. in length, and from 3 mm. to 4 mm. in breadth, and usually present the appearance of flattened oval discs. They are divided, according to their situation, into *superior* and *inferior*. The superior, usually two in number, are the more constant in position, and are situated one on either side, at the level of the lower border of the cricoid cartilage, behind the junction of the pharynx and œsophagus. The inferior, also usually two in number, may be applied to the lower edge of the lateral lobes of the thyroid gland, or placed at some little distance below the thyroid gland, or found in relation to one of the inferior thyroid veins.*

In man, they number four as a rule; fewer than four were found in less than 1 per cent. of over a thousand persons (Peperé †) but more than four in over 33 per cent. of 122 bodies examined by Civalleri. In addition, numerous minute islands of parathyroid tissue may be found scattered in the connective tissue and fat of the neck round the parathyroid glands proper, and quite distinct from them.

Structure.—Microscopically the parathyroid glands consist of intercommunicating columns of cells supported by connective tissue containing a rich supply of blood-capillaries. Most of the cells are clear, but some, larger in size, contain oxyphil granules. Vesicles containing colloid have been described as occurring in the parathyroids.

Applied Anatomy.—No doubt the parathyroid glands produce an internal secretion essential to the well-being of the human economy; but it is still a matter of dispute what symptoms of disease are produced by their removal and suppression of their secretion. Peperé believes that they show signs of exceptional activity during pregnancy, and that parathyroid insufficiency is a main factor in the production of tetany in infants and adults, of eclampsia, and of certain sorts of fits.

THE THYMUS (fig. 1105)

The thymus is a temporary organ, attaining its largest size at the time of puberty (Hammar), when it ceases to grow, gradually dwindles, and almost disappears. If examined when its growth is most active, it will be found to consist of two lateral lobes placed in close contact along the middle line, situated partly in the thorax, partly in the neck, and extending from the fourth costal cartilage upwards, as high as the lower border of the thyroid gland. It is covered by the sternum, and by the origins of the Sternohyoidei and Sternothyroidei. Below, it rests upon the pericardium, being separated from the aortic arch and great vessels by a layer of fascia. In the neck it lies on the front and sides of the trachea, behind the Sternohyoidei and Sternothyroidei. The two lobes generally differ in size; they are occasionally united, so as to form a single mass; and sometimes separated by an intermediate lobe. The thymus is of a pinkish-grey colour, soft, and lobulated on its surfaces. It is about 5 cm. in length, 4 cm. in breadth below, and about 6 mm. in thickness. At birth it weighs about 15 gm.; at puberty, between 35 and 40 gm.

* Consult an article by D. A. Welsh, *Journal of Anatomy and Physiology*, vol. xxxii.

† Consult *Le Ghiandole paratiroides*, by A. Peperé, Turin, 1906.

FIG. 1105.—The thymus of a full-time fœtus, exposed *in situ*.

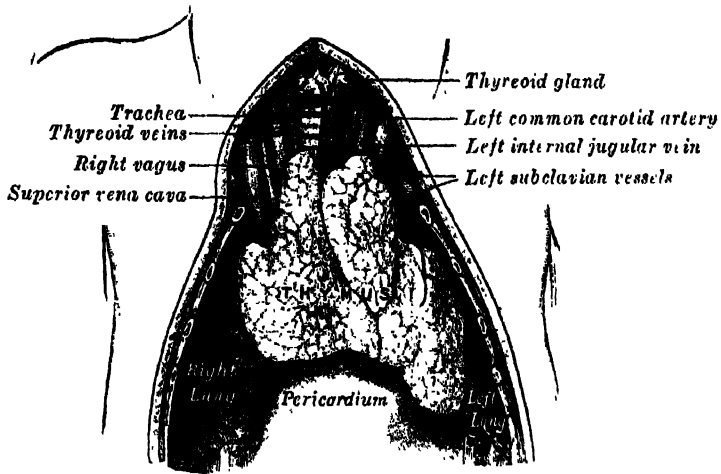
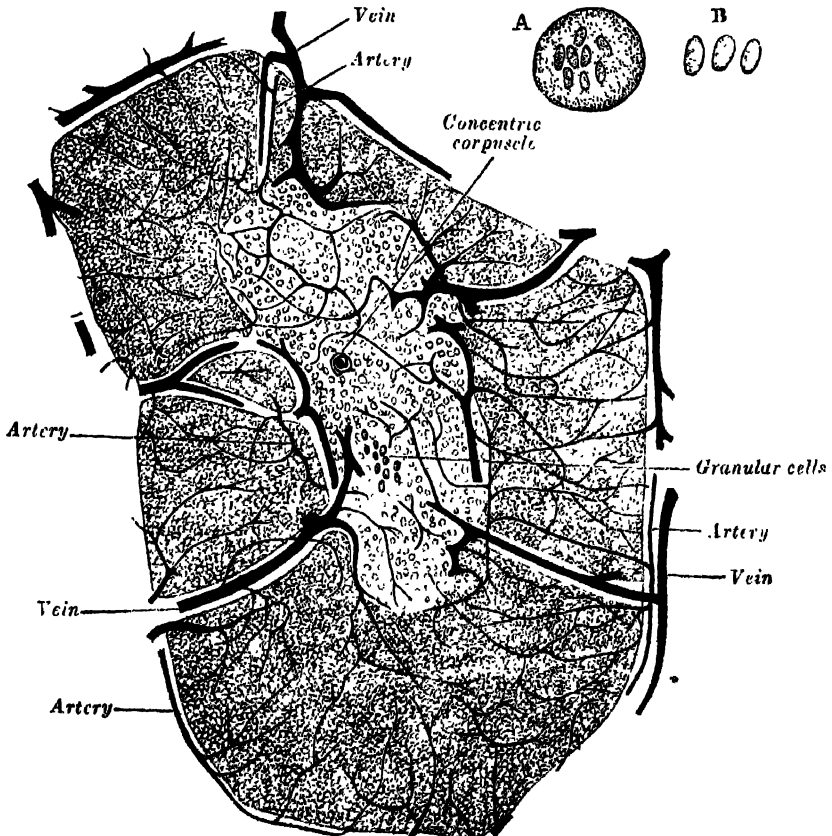


FIG. 1106.—The minute structure of the thymus. A follicle of the injected thymus of a calf, four days old. Slightly diagrammatic. Magnified about 50 diameters. The large vessels are disposed in two rings, one of which surrounds the follicle, the other lies just within the margin of the medulla. (Watney.)



* A. and B. From the thymus of a camel, examined without the addition of any reagent. Magnified about 400 diameters. A. Large colourless cell, containing small oval masses of haemoglobin. Similar cells are found in the lymph-glands, spleen, and medulla of bone. B. Coloured blood-corpuscles.

Structure.—Each lateral lobe is composed of numerous lobules held together by delicate areolar tissue; the entire gland being enclosed in an investing capsule of a similar but denser structure. The primary lobules vary in size and are made up of a number of small nodules or follicles, which are irregular in shape and are more or less fused together, especially towards the interior of the gland. Each follicle is from 1 mm. to 2 mm. in diameter and consists of a cortical and a medullary portion; it is enclosed in a connective tissue capsule, from which septa pass into its substance, but do not extend as far as the medullary portion of the follicle. The cortical portion is mainly composed of lymphocytes, supported by a network of finely branched cells, which is continuous with a similar network in the medullary portion. This network forms an adventitia to the blood-vessels. In the medullary portion the reticulum is coarser than in the cortex, the lymphoid cells are relatively fewer in number, and there are found peculiar nest-like bodies, the concentric corpuscles of Hassall. These corpuscles are composed of a central mass, consisting of one or more granular cells, and of a capsule which is formed of concentrically arranged epithelioid cells (fig. 1106). Eosinophil and polymorphonuclear leucocytes are also found in the gland.

Each follicle is surrounded by a vascular plexus, from which vessels pass into the interior, and radiate from the periphery towards the centre, forming a second zone just within the margin of the medullary portion. In the centre of the medullary portion there are very few vessels, and they are of minute size (fig. 1106).

Watney observed that hæmoglobin is found in the thymus, either in cysts or in cells situated near to, or forming part of, the concentric corpuscles. This hæmoglobin occurs as granules or as circular masses exactly resembling coloured blood-corpuscles. He has also discovered, in the lymph issuing from the thymus, similar cells to those found in the gland, and, like them, containing hæmoglobin in the form of either granules or masses. From these facts he arrives at the conclusion that the gland is one source of the coloured blood-corpuscles. More recently Schaffer has observed actual nucleated red blood-corpuscles in the thymus.

Vessels and Nerves.—The arteries supplying the thymus are derived from the internal mammary, and from the superior and inferior thyroids. The veins end in the left innominate vein, and in the thyroïd veins. The lymphatics are described on p. 730. The nerves are exceedingly minute; they are derived from the vagi and sympathetic. Branches from the descendens hypoglossi and phrenic reach the investing capsule, but do not penetrate into the substance of the gland.

Applied Anatomy.—Sudden death—'thymus death'—with heart-failure, and with or without acute respiratory embarrassment, has been recorded in a number of infants and children in whom the thymus was considerably enlarged, and the lymphatic tissues throughout the body showed general hypertrophy, but who showed no other evidence of disease. Such deaths have often occurred during the administration of anæsthetics, particularly chloroform. How far the enlarged thymus was responsible for the death of these patients, and, if it was responsible, how far its action was mechanical, are points that have been much disputed. Short of producing this sudden death, it appears that thymic enlargement may cause attacks of respiratory stridor, or noisy and difficult breathing, and spasmodic attacks of asthma—'thymic asthma'—which may be frequently repeated and may even result in death. Primary tumours of the thymus are rare forms of mediastinal new growth, and are usually sarcomas.

THE SPLEEN (LIEN)

The spleen is situated principally in the left hypochondriac region, but its superior extremity extends into the epigastric region; it lies between the fundus of the stomach and the Diaphragm. It is the largest of the ductless glands, and is of an oblong, flattened form, soft, of very friable consistence, highly vascular, and of a dark purplish colour.

Relations.—The diaphragmatic surface is convex, smooth and is directed upwards, backwards, and to the left, except at its upper end, where it is directed slightly medialwards. It is in relation with the under surface of the Diaphragm, which separates it from the ninth, tenth, and eleventh ribs of the left side, and the intervening lower border of the left lung and pleura.

The visceral surface (fig. 1107) is divided by a ridge into an anterior or gastric, and a posterior or renal portion.

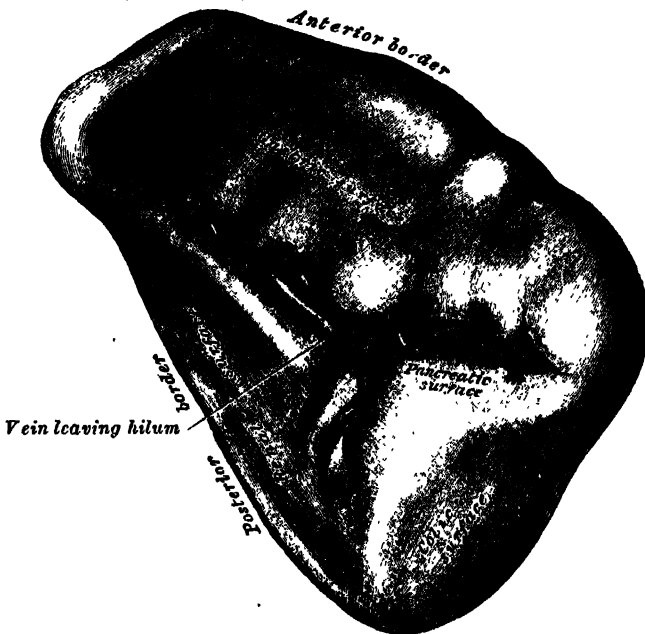
The gastric surface, which is directed forwards, upwards, and medialwards, is broad and concave, and is in contact with the posterior wall of the stomach; and below this with the tail of the pancreas. It presents near its medial border a long fissure, termed the *hilum*. This is pierced by several irregular apertures for the entrance and exit of vessels and nerves.

The renal surface is directed medialwards and downwards. It is somewhat flattened, is considerably narrower than the gastric surface, and is in relation

with the upper part of the anterior surface of the left kidney and occasionally with the left suprarenal gland.

The *superior extremity* is directed towards the vertebral column, where it lies on a level with the eleventh thoracic vertebra. The *lower extremity* or *colic surface* is flat, triangular in shape, and rests upon the left flexure of the colon and the phrenicocolic ligament, and is generally in contact with the tail of the pancreas. The *anterior border* is free, sharp, and thin, and is often notched near its lower end; it separates the diaphragmatic from the gastric surface. The *posterior border*, blunter and more rounded than the anterior, separates the renal from the diaphragmatic surface; it corresponds to the lower border of the eleventh rib and lies between the Diaphragm and left

FIG. 1107.—The visceral surface of the spleen.



kidney. The *intermediate margin* is the ridge which separates the renal and gastric surfaces. The *inferior border* separates the diaphragmatic from the colic surface.

The spleen is almost entirely surrounded by peritoneum, which is firmly adherent to its capsule. It is in position by two folds of this membrane. One, the *phrenicocolic ligament*, is derived from the peritoneum where the wall of the general peritoneal cavity comes into contact with the omental bursa between the left kidney and the spleen, the lienal vessels pass between its two layers (fig. 1003). The other fold, the *gastrolieal ligament*, is also formed of two layers, derived from the wall of the general peritoneal cavity and the omental bursa respectively, where they meet between the spleen and stomach (fig. 1003); the short gastric and left gastro-epiploic branches of the lienal artery run between its two layers. The lower end of the spleen is supported by the phrenicocolic ligament (p. 1096).

The size and weight of the spleen vary at different periods of life, in different individuals, and in the same individual under different conditions. In the *adult*, it is usually about 12 cm. in length, 7 cm. in breadth, and 3 or 4 cm. in thickness, and weighs about 200 gm. The size of the spleen slowly increases during digestion, and varies according to the state of nutrition of the body, being large in highly fed, and small in starved, animals. In malarial fever it is greatly enlarged, and may weigh as much as 2 kilos.

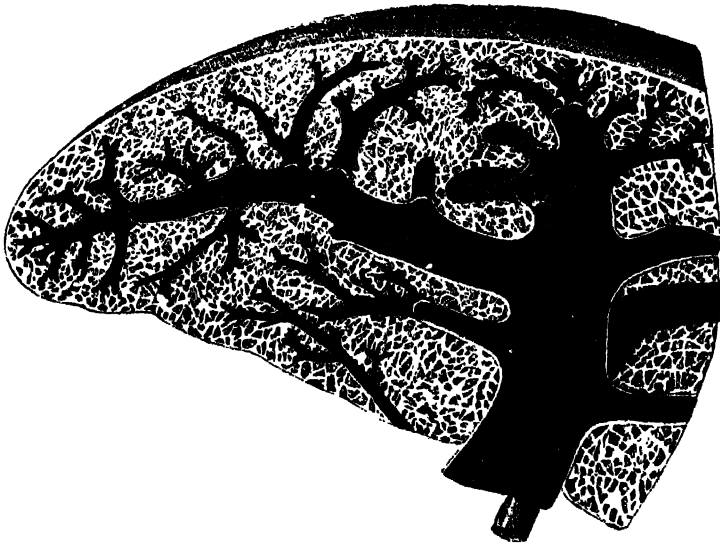
Frequently in the neighbourhood of the spleen, and especially in the gastrolial ligament and greater omentum, small encapsulated nodules of splenic tissue may be found, either isolated or connected to the spleen by thin bands of splenic tissue. They are known as *accessory spleens*.

Structure.—The spleen is invested by two coats; an external serous and an internal fibro-elastic coat.

The *external or serous coat* is derived from the peritoneum; it is thin, smooth, and in the human subject intimately adherent to the fibro-elastic coat. It invests the entire organ, except at the hilum and along the lines of reflection of the phrenicolial and gastrolial ligaments.

The *fibro-elastic coat or tunica propria* invests the organ, and at the hilum is reflected inwards upon the vessels in the form of sheaths. From these sheaths, as well as from the inner surface of the fibro-elastic coat, numerous small fibrous bands, *trabeculae* (fig. 1108), are given off in all directions; these unite to form the framework of the spleen, in the interspaces of which is contained the *splenic pulp*.

FIG. 1108.—A transverse section through the spleen, showing the trabecular tissue and the splenic vein and its tributaries.



The fibro-elastic coat, the sheaths of the vessels, and the trabeculae, are composed of white, and yellow elastic, fibres, the latter predominating. It is owing to the presence of the elastic tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents there is a small amount of non-striped muscular fibre. In some mammals (e.g. dog, pig, and cat) the trabeculae consist chiefly of muscular tissue.

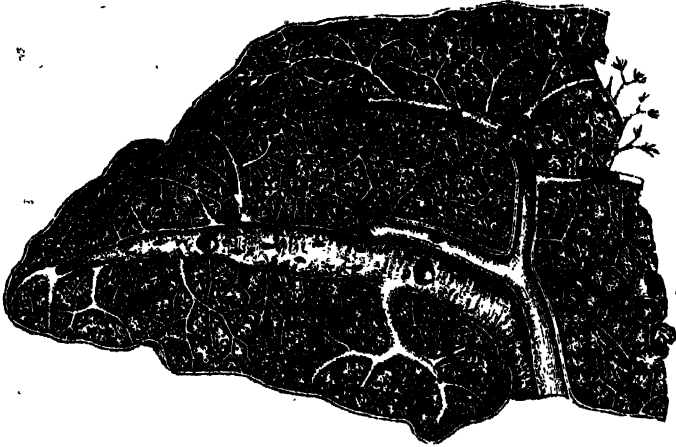
The *splenic pulp* is a soft mass of a dark reddish-brown colour; it consists of a fine reticulum of fibres, continuous with those of the trabeculae, to which are applied flat, branching cells. The meshes of the reticulum are filled with blood, in which, however, the white corpuscles are found to be in larger proportion than they are in ordinary blood. Large, rounded cells, termed *splenic cells*, are also seen; these are capable of amoeboid movement, and often contain pigment and red blood corpuscles in their interior. The cells of the reticulum each possess a round or oval nucleus, and like the splenic cells they may contain pigment granules in their cytoplasm; they do not stain deeply with carmine, and in this respect differ from the cells of the Malpighian bodies. In the young spleen giant cells may be found, each containing numerous nuclei or one compound nucleus. Nucleated red blood corpuscles have also been found in the spleen of young animals.

Blood-vessels of the spleen.—The lienal artery is remarkable for its large calibre in proportion to the size of the organ, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance (fig. 1109) receiving sheaths from an involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

Each branch runs in the transverse axis of the organ, from within outwards, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior part. These ultimately leave the trabecular

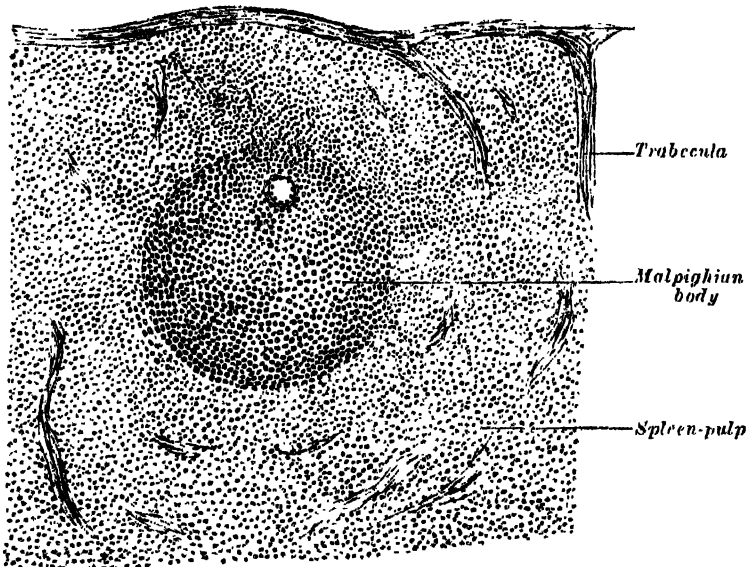
sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells. Each of the larger branches of the artery supplies chiefly that region of the organ in which the branch ramifies, having no anastomosis with the majority of the other branches.

FIG. 1109.—Transverse section of the human spleen, showing the distribution of the splenic artery and its branches.



The *arterioles* differ in structure from the larger arterial vessels in that their *outer coat consists of lymphoid tissue*. This coat exhibits localized spheroidal thickenings, termed the *Malpighian bodies* of the spleen (fig. 1110). These bodies vary in size from about 0.25 mm. to 1 mm. in diameter. In transverse sections, the artery, in the majority of cases, is found in an *eccentric position*. The Malpighian bodies are visible to the

FIG. 1110.—Transverse section of a portion of the spleen.



naked eye on the surface of a fresh section of the organ, appearing as minute semi-opaque dots of a whitish colour in the dark substance of the pulp. The reticulum of the adenoid tissue is made up of extremely fine fibrils, and is comparatively open in the centre of the body, but closer at its periphery.

The arterioles end by opening freely into the splenic pulp; their walls become much attenuated, they lose their tubular character, and the endothelial cells ramify, their

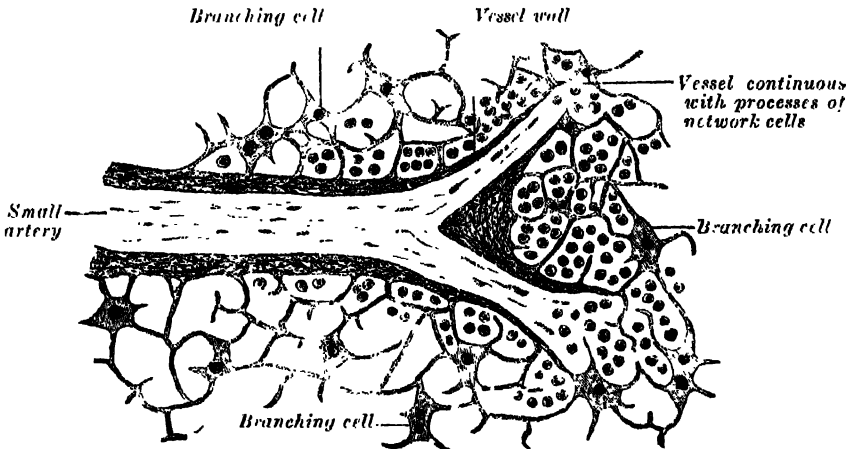
processes being directly connected with those of the reticular cells of the pulp (fig. 1111). The blood thus finds its way into the interstices of the reticulated tissue of the splenic pulp. It is then collected by the rootlets of the veins, which begin much in the same way as the arteries end. The connective tissue corpuscles of the pulp arrange themselves in rows, in such a way as to form an elongated space or sinus. They become elongated and spindle-shaped, and overlap each other at their extremities, and thus form a sort of endothelial lining of the path or sinus, which is the radicle of a vein. On the outer surface of these cells are seen delicate transverse lines or markings, which are due to minute elastic fibrils arranged in a circular manner around the sinus. Thus the channel obtains an external investment, and gradually becomes converted into a small vein, which after a short course acquires a coat of ordinary connective tissue, lined by a layer of flattened epithelial cells continuous with the supporting cells of the pulp. The smaller veins unite to form larger ones; these do not accompany the arteries, but soon enter the trabecular sheaths of the capsule, and by their junction form six or more branches, which emerge from the hilum, and, uniting, constitute the lienal vein, the largest radicle of the portal vein.

The veins are remarkable for their numerous anastomoses, while the arteries hardly anastomose at all.

The lymphatics are described on p. 732.

The nerves are derived from the coeliac plexus and are chiefly non-medullated. They are distributed to the blood-vessels and to the smooth muscle of the capsule and trabeculae.

FIG. 1111.- A section of the spleen, showing the termination of a small blood-vessel.



Applied Anatomy.—Injury of the spleen is less common than that of the liver, on account of its protected situation and connexions. It may be ruptured by direct or indirect violence; torn by a broken rib; or injured by a punctured or gunshot wound. When the organ is enlarged, the chance of rupture is increased. The great risk is hæmorrhage, owing to the vascularity of the organ and the absence of a proper system of capillaries. The injury is not, however, necessarily fatal, and this would appear to be due, in a great measure, to the contractile power of the capsule, which narrows the wound and prevents the escape of blood. In cases where the diagnosis is clear, and the symptoms indicate danger to life, laparotomy must be performed, and the spleen removed.

The spleen may become enormously enlarged in certain diseased conditions, such as ague, leucæmia, syphilis, valvular disease of the heart, or without any obtainable history of previous disease. It may also become enlarged in lymphadenoma, as a part of a general blood-disease. In these cases the tumour may fill a considerable part of the abdomen and extend into the pelvis, and may be mistaken for ovarian or uterine new growth.

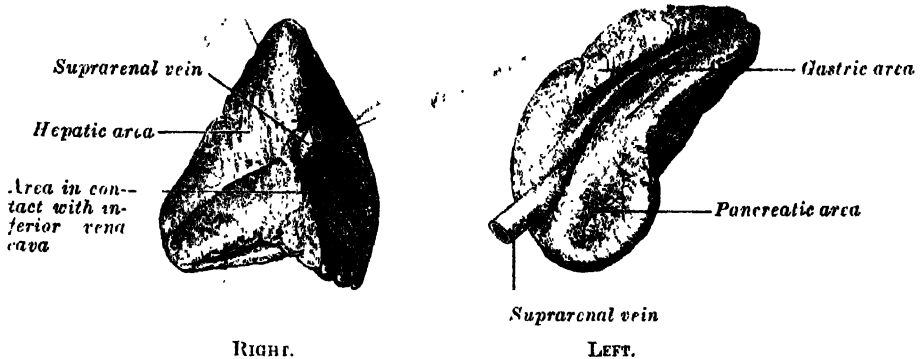
The spleen is sometimes the seat of cystic tumours, especially hydatids, and of abscess. These cases require treatment by incision and drainage; and in abscess great care must be taken, if there are no adhesions between the spleen and abdominal wall, to prevent the escape of any of the pus into the peritoneal cavity.

Extirpation of the spleen has been performed for wounds or injuries, in floating spleen, in simple hypertrophy, in leucæmic enlargement (but the operation is now considered unjustifiable in this condition), and in the case of enlargement due to certain obscure parasitic infections met with in hot climates. The incision is best made in the left semi-lunar line; the spleen is isolated from its surroundings and delivered from the abdomen; the pedicle is then transfixed and ligatured in two portions.

SUPRARENAL GLANDS (figs. 1112, 1113)

The suprarenal glands are two small flattened bodies of a yellowish colour, situated at the posterior part of the abdomen, behind the peritoneum, and immediately above and in front of the upper end of either kidney; hence their name. They are surrounded by areolar tissue containing a considerable amount of fat. The right one is somewhat triangular in shape, bearing a resemblance to a cocked hat; the left is more semilunar, usually larger and

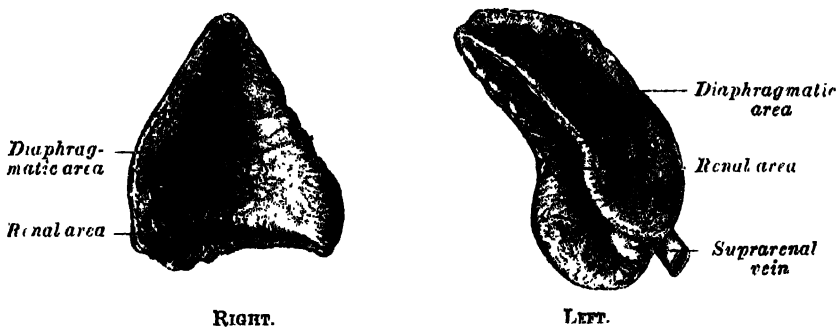
FIG. 1112.—The suprarenal glands. Viewed from the front.



placed at a higher level than the right. They measure from 30 mm. to 50 mm. in height; about 30 mm. in breadth, and from 4 mm. to 6 mm. in thickness. The average weight of each is from 3 gm. to 4 gm.

Relations.—The *right suprarenal gland* is situated behind the inferior vena cava and right lobe of the liver, and in front of the Diaphragm and upper end of the right kidney. It is roughly triangular in shape; its base, directed downwards, is in contact with the medial and anterior surfaces of the upper end of the right kidney. Its *anterior surface* looks forwards and lateralwards,

FIG. 1113.—The suprarenal glands. Viewed from behind.

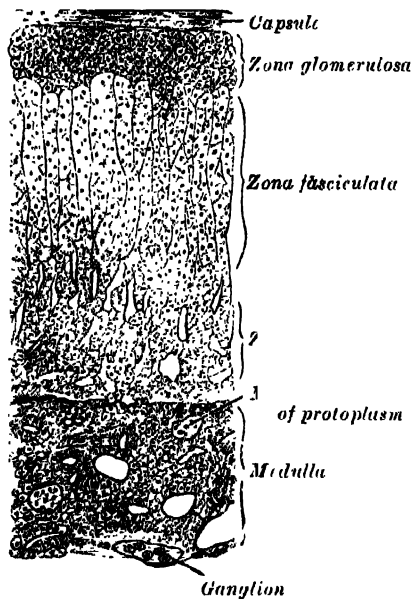


and has two areas: a medial, narrow and non-peritoneal, which lies behind the inferior vena cava; and a lateral, somewhat triangular, in contact with the liver. The upper part of the latter surface is devoid of peritoneum, and is in relation with the bare area of the liver near its lower and medial angle, while its inferior portion may be covered by peritoneum, reflected on to it from the inferior layer of the coronary ligament; occasionally the duodenum overlaps the inferior portion. A little below the apex, and near the anterior border of the gland, is a short furrow termed the hilum, from which the right suprarenal vein emerges to join the inferior vena cava. Its *posterior surface*

is divided into upper and lower parts by a curved ridge; the upper, slightly convex, rests upon the Diaphragm; the lower, concave, is in contact with the upper end and the adjacent part of the anterior surface of the kidney.

The *left suprarenal gland*, slightly larger than the right, is crescentic in shape, its concavity being adapted to the medial border of the upper part of the left kidney. Its medial

FIG. 1114.—A section through a part of a suprarenal gland. (Magnified.)



border is convex, its lateral, concave; its upper end is narrow, its lower, rounded. Its *anterior surface* has two areas: an upper, covered by the peritoneum of the omental bursa, which separates it from the cardiac end of the stomach and sometimes from the superior extremity of the spleen; and a lower, which is not covered by peritoneum, but is in contact with the pancreas and lienal artery. Near the lower part of the anterior surface is the hilum, which is directed downwards and forwards. From it the left suprarenal vein emerges to join the left renal vein. Its *posterior surface* is divided into two areas by a vertical ridge; the lateral area rests on the kidney, the medial and smaller, on the left crus of the Diaphragm.

Small *accessory suprarenals* are often found in the connective tissue round the suprarenals.

Structure.—The suprarenal gland is closely invested by a capsule of connective tissue from which trabeculae pass into the substance of the gland; the capsule may contain smooth muscle fibres. On section, the gland is seen to consist of two portions (fig. 1114): an external or cortical, and an internal or medullary. The former constitutes the larger part of the organ, and is of a deep yellow colour; the medullary substance is soft, pulpy, and of a dark red or brown colour.

The *cortical portion* consists of a fine connective tissue network, in which is imbedded the glandular epithelium. The epithelial cells are polyhedral in shape and possess rounded nuclei; many of the cells contain coarse granules, others lipid globules. Owing to differences in the arrangement of the cells three distinct zones can be made out: (1) The *zona glomerulosa*, situated beneath the capsule, consists of cells arranged in rounded groups, with here and there indications of an alveolar structure. (2) The *zona fasciculata*, continuous with the zona glomerulosa, is composed of columns of cells arranged in a radial manner; these cells contain finer granules and in many instances globules of lipid material. (3) The *zona reticularis*, in contact with the medulla, consists of cylindrical columns of cells irregularly arranged; these cells often contain pigment-granules which give this zone a darker appearance than the rest of the cortex.

The *medullary portion* is extremely vascular, and is composed of a network of large cells, the interspaces containing large venous sinusoids. The cells forming the network are finely granular, and have an especial affinity for chromic salts, which stain them a brown colour. Such cells are therefore termed *chromaffin cells* (p. 101). This portion of the gland is richly supplied with non-medullated nerve-fibres, and here and there sympathetic ganglia are found.

The suprarenal gland is large in the foetus, owing to the great development of the inner layer of the cortex. This layer has been named the *boundary zone* by Elliott and Armour. Its cells contain no lipid granules. This zone disappears soon after birth and is absent in anencephalic foetuses.

In connexion with the development of the medulla from the sympathochromaffin tissue, it is to be noted that this portion of the gland secretes a substance, *adrenalin*, which has the property of stimulating all sympathetic nerve-endings.

Vessels and Nerves.—The arteries supplying the suprarenal glands are numerous and of comparatively large size; they are derived from the aorta, the inferior phrenic, and the renal. In the cortical part of the gland they break up into capillaries which end in the sinusoids of the medullary portion; the latter open into the veins near the centre of the medulla.

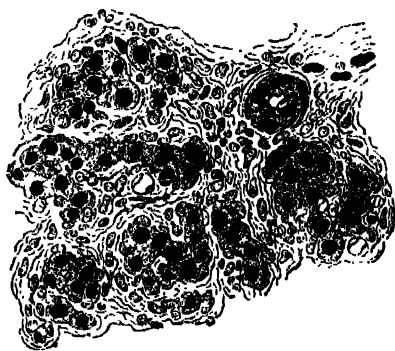
The *suprarenal vein* emerges from the hilum of the gland, and on the right side opens into the inferior vena cava, on the left into the renal vein.

The *lymphatics* end in the lumbar glands.

The *nerves* are exceedingly numerous, and are derived from the coeliac and renal plexuses, and, according to Bergmann, from the phrenic and vagus nerves. They enter the lower and medial part of the capsule, traverse the cortex, and end around the cells of the medulla. They have numerous small ganglia developed upon them in the medullary portion of the gland.

Applied Anatomy.—The suprarenal cortex is derived from the ectodermic epithelium of the Wolffian ridge, and is connected with the sexual glands; it is related to growth and development in some way, and is often found to be hypertrophied in patients with chronic kidney disease and high blood-pressure. The *medulla*, on the other hand, is neuro-ectodermal in origin, and closely connected with the sympathetic nervous system. When the suprarenal medulla is destroyed by tuberculosis, to which the glands are prone, or by the pressure of a new growth, the secretion of adrenalin becomes inadequate, and Addison's disease develops. Patients with Addison's disease become pigmented in various parts of the body, possibly from irritation of the sympathetic, and complain of great weakness, lack of energy, nausea, and severe attacks of vomiting. Their blood-

FIG. 1115.—A section of a part of a human glomus caroticum. (Schaper.) Highly magnified. (From Quain's Elements of Anatomy, Vol. II. Pt. I.)



Numerous blood-vessels are seen in section among the gland-cells.

pressure is low, the whole nervous system is depressed, and death follows after a period of months or years, usually from asthenia. Tumours derived from the suprarenal itself, or from misplaced suprarenal 'rests' occurring in such organs as the kidney or liver, may be either benign or malignant, and are classed together under the name 'hypernephroma.' In children the malignant hypernephroma is often associated with obesity and precocity. The benign hypernephroma, or suprarenal adenoma, appears to produce no symptoms except those due to its slow enlargement.

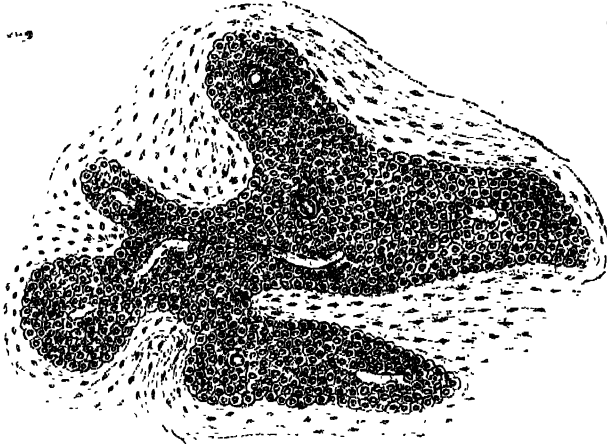
The *glomera carotica* (carotid bodies), two in number, are situated one on either side of the neck, behind the common carotid artery at its point of bifurcation into the external and internal carotid trunks. They are reddish-brown in colour and oval in shape, the long diameter measuring about 5 mm.

Structure.—Each glomus is invested by a fibrous capsule and consists largely of spherical or irregular masses of chromaffin cells (fig. 1115)—the masses being more or less isolated from one another by septa which extend inwards from the deep surface of the capsule. The cells are polyhedral in shape, and each contains a large nucleus imbedded in finely granular protoplasm. Numerous nerve-fibres, derived from the sympathetic plexus on the carotid artery, are distributed throughout the organ, and a network of large sinusoidal capillaries ramifies amongst the cells.

The *glomus coccygeum* (coccygeal body) is placed in front of, or immediately below, the tip of the coccyx. It is about 2.5 mm. in diameter and is irregularly oval in shape; several smaller nodules are found around or near the main mass.

Structure.—The glomus coecygeum consists of irregular masses of round or polyhedral cells (fig. 1116), the cells of each mass being grouped around a dilated sinusoidal capillary vessel. Each cell contains a large round or oval nucleus, the protoplasm surrounding which is clear and is not stained by chromic salts.*

FIG. 1116.—Section of an irregular nodule of the glomus coecygeum. $\times 85$.
(Sertoli.) (From Quain's Elements of Anatomy, Vol. II. Pt. I.)



The section shows the fibrous covering of the nodule, the blood-vessels within it, and the epithelial cells of which it is constituted.

Besides the ductless glands mentioned, reference may be made to a pair of small bodies, the **aortic bodies of Zuckerkandl**. These are found in the embryo, and persist until shortly after birth; they lie one on either side of the abdominal aorta between the superior mesenteric and common iliac arteries (p. 101). They consist essentially of masses of polygonal or cuboidal chromaffin cells imbedded in a wide-meshed capillary plexus.

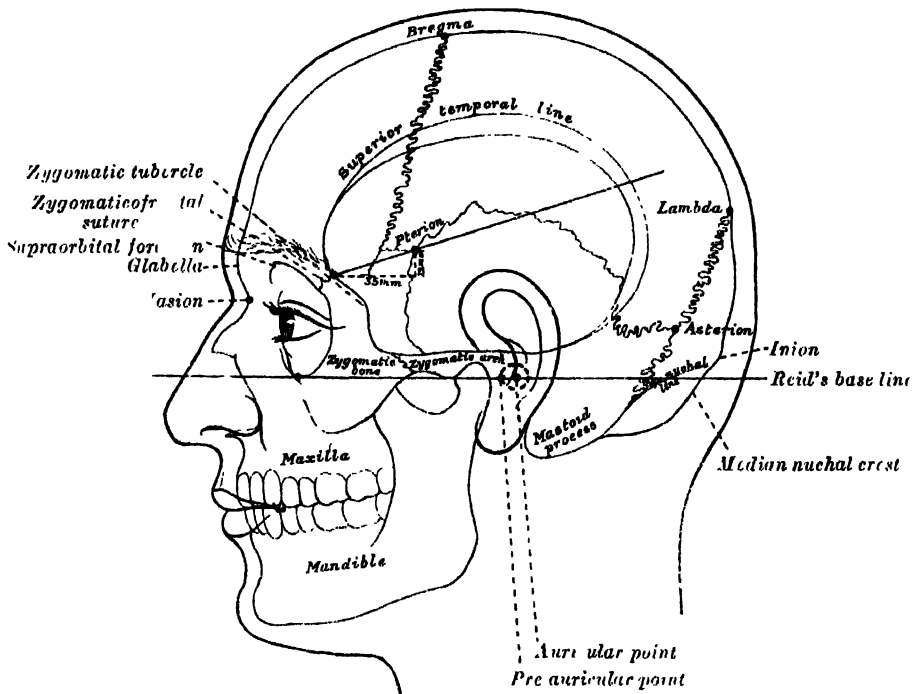
* Consult the following article: 'Über die menschliche Steissdrüse,' von J. W. Thomson Walker, *Archiv für mikroskopische Anatomie und Entwicklungsgeschichte*, Band 64, 1904.

SURFACE ANATOMY AND SURFACE MARKINGS

SURFACE ANATOMY OF THE HEAD AND NECK

Bones (fig. 1117).—The *external occipital protuberance* (inion) is situated behind, in the middle line, at the upper end of the nuchal furrow, and the *superior nuchal lines* run lateralwards from it, one on either side. Above these lines the vault

FIG. 1117.—Side view of head, showing surface relations of bones.



of the cranium is so thinly covered with soft structures that the form of this part of the head is almost that of the upper portion of the occipital, the parietal and the frontal bones. The superior nuchal lines run lateralwards to the mastoid portions of the temporal bones, from which the *mastoid processes* project downwards and forwards behind the auriculæ. The anterior and posterior borders, the apex, and the external surface of the mastoid process are available for surface examination; the anterior border lies immediately behind the concha, and the apex is nearly on a level with the lobule of the auricula. The *transverse process of the atlas* is deeply placed, about 1 cm. below and in front of the apex of the mastoid process. In front of the ear the *zygomatic arch* can be felt throughout its entire length; its narrow posterior end is situated a little above the level of the tragus; its broad

anterior end is continued into the zygomatic bone. The upper border of the arch is less distinct than the lower, but can be followed into the *superior temporal line*. Anteriorly, this line begins at the zygomatic process of the frontal bone as a curved ridge which runs at first forwards and upwards and then backwards on the frontal bone, separating the forehead from the temporal fossa. It then crosses the parietal bone, where, though less marked, it can generally be recognised. Finally, it curves downwards and forwards, and, passing above the opening of the external acoustic meatus, ends in the posterior root of the zygomatic arch.

Near the line of the greatest transverse diameter of the head are the *parietal tuberosities*, one on either side; further forwards, on the forehead, are the *frontal tuberosities*, which vary in prominence in different individuals and are sometimes unsymmetrical. Below the frontal tuberosities are the *superciliary arches*, which indicate the position of the frontal sinuses; they are absent in infancy, and are, as a rule, small in the female. In some cases the prominence of these arches is related to the size of the frontal sinuses, but frequently there is no such relationship. Between the superciliary ridges is a smooth, somewhat triangular area, the *glabella*, and below this is the *nasion* or frontonasal suture.

Below the nasion the *nasal bones*, scantily covered by soft tissues, can be traced to their junctions with the nasal cartilages, and on either side of the nasal bones the complete outline of the *orbital margin* can be made out. At the junction of the medial with the intermediate third of the supraorbital margin the *supraorbital notch*, when present, can be felt; near the medial end of the infraorbital margin is a little tubercle which serves as a guide to the position of the lacrimal sac. Below and lateral to the orbit, on either side, the *zygomatic bone* forms the prominence of the cheek; its posterior margin is easily felt, and on it just above the level of the lateral palpebral commissure is the *zygomatic tubercle*. A slight depression, about 1 cm. above this tubercle, indicates the position of the *zygomaticofrontal suture*. Below the orbit a considerable part of the anterior surface, and the whole of the alveolar process, of the *maxilla*, can be palpated. Almost the entire outline of the *mandible* can be recognised; the condyle lies in front of the tragus and below the zygomatic arch, and from it the posterior border of the ramus descends to the angle; from the angle to the symphysis the lower rounded border of the body of the bone is readily traced; the lower part of the anterior border of the ramus and the alveolar process can be made out without difficulty. In the receding angle below the chin is the *hyoid bone*, and the finger can be carried along the bone to the tip of its greater cornu, which is most readily appreciated by making pressure on one side of the bone, when the cornu of the opposite side is rendered prominent beneath the skin.

The transverse processes of the first, sixth, and seventh cervical vertebræ can be felt. That of the first is about 1 cm. below and in front of the mastoid process of the temporal bone; that of the sixth is opposite to, and that of the seventh a little below, the cricoid cartilage.

Joints and muscles.—The *temporomandibular articulation* is superficial and is situated below the posterior end of the zygomatic arch, in front of the external acoustic meatus. Its position can be ascertained by defining the condyle of the mandible; when the mouth opens, the condyle advances out of the mandibular fossa on to the articular tubercle of the temporal bone, and a depression is felt in the situation of the joint.

With the exceptions of the *Masseter* and *Temporalis* the outlines of the muscles of the head and face cannot be traced on the surface. The *Masseter* imparts fullness to the hinder part of the cheek; if firmly contracted, as when the teeth are clenched, its quadrilateral outline is plainly visible; its anterior border forms a prominent vertical ridge, behind which is a considerable fullness especially marked at the lower part of the muscle. The *Temporalis*, a fan-shaped muscle, fills the temporal fossa, and stands out in strong relief when in action. The muscles of the scalp are so thin that the contour of the skull is perceptible beneath them. Those of the face are small, covered by soft skin and often by a considerable layer of fat, and their outlines are therefore concealed; they serve, however, to round off and smooth prominent borders, and to fill up what would otherwise be unsightly angular depressions. Thus the *Orbicularis oculi* rounds off the prominent margin of the orbit, and the *Procerus* fills in the sharp depression below the glabella. In like manner the *labial muscles*, converging to the lips, and assisted by the superimposed fat, fill up the sunken hollow of the lower part of the face. When in action the

facial muscles produce the various expressions, and in addition throw the skin into numerous folds and wrinkles.

By the contraction of the *Platysma* the skin of the neck is thrown into oblique ridges parallel with the fasciuli of the muscle. The *Sternocleidomastoideus* has the most important influence on the surface form of the neck (figs. 1118, 1119). When the muscle is at rest its anterior border forms an oblique rounded edge ending below in the outline of the sternal head; the posterior border is only distinct for about 2 cm. or 3 cm. above the middle of the clavicle. When the muscle is contracted, the sternal head stands out as a sharply defined ridge, while the clavicular head is flatter and less prominent; between the two heads is a slight depression. The middle portion of the muscle appears as an oblique elevation with a thick,

FIG. 1118.—Anterolateral view of head and neck.



anterior border, best marked in its lower part. The sternal heads of the two muscles are separated by a V-shaped depression (jugular notch) in which are the *Sternohyoideus* and *Sternothyroideus*.

Above the hyoid bone, near the middle line, the anterior belly of *Digastricus* gives rise to a slight convexity.

The anterior border of the *Trapezius* produces a faint ridge running downwards and forwards from the superior nuchal line to the junction of the intermediate with the lateral third of the clavicle. Between the *Sternocleidomastoides* and the *Trapezius* is the posterior triangle of the neck, the lower part of which appears as a shallow concavity—the supraclavicular fossa. In this fossa, the inferior belly of *Omohyoideus*, when in action, causes a cord-like elevation a little above and almost parallel to the clavicle.

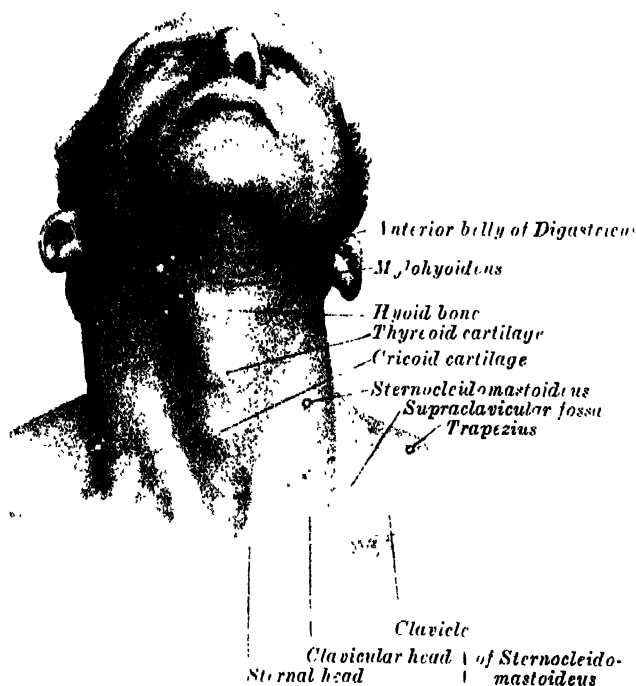
Arteries.—The positions of several of the larger arteries can be ascertained from their pulsations.

The *subclavian artery* is felt on making pressure downwards, backwards, and medialwards behind the lateral margin of the clavicular head of the *Sternocleidomastoides*; its *transverse cervical* branch may be detected parallel to, and about a finger's breadth above, the clavicle. The *common* and *external carotid arteries*

can be recognised immediately beneath the anterior edge of the Sternocleidomastoideus, and the *external maxillary artery* traced over the inferior border of the mandible at the anterior edge of the Masseter. The pulsation of the *occipital artery* may be felt about 3 cm. or 4 cm. laterally to the external occipital protuberance, and that of the *posterior auricular* in the groove between the mastoid process and the auricula. The course of the *superficial temporal artery* can be readily followed upwards across the posterior end of the zygomatic arch to a point about 4 cm. above the arch, where it divides into its frontal and parietal branches; the pulsation of the frontal branch is frequently visible on the side of the forehead. The *supra-orbital artery* can usually be detected immediately above the supraorbital notch or foramen.

Larynx and Trachea.—In the receding angle below the chin, the hyoid bone (p. 1210), situated opposite the lower part of the third cervical vertebra, can easily

FIG. 1119.—Front view of neck.



be made out. A finger's-breadth below it, is the laryngeal prominence (pomum Adami) of the thyroid cartilage; the space between the hyoid bone and the thyroid cartilage is occupied by the thyrohyoid membrane. The outlines of the alæ and cornua of the thyroid cartilage are readily palpated; below this cartilage is a depression corresponding to the middle cricothyroid ligament. The level of the vocal folds (true vocal cords) corresponds to the middle of the anterior margin of the thyroid cartilage. The anterior part of the cricoid cartilage forms an important landmark on the front of the neck; it lies opposite the sixth cervical vertebra, and indicates the junctions of the pharynx with the œsophagus, and of the larynx with the trachea. Below the cricoid cartilage the trachea can be felt, but only in thin subjects are its rings distinguishable; as a rule there are seven or eight rings above the jugular notch of the sternum, and of these the second, third, and fourth are covered by the isthmus of the thyroid gland. The normal thyroid gland cannot be felt.

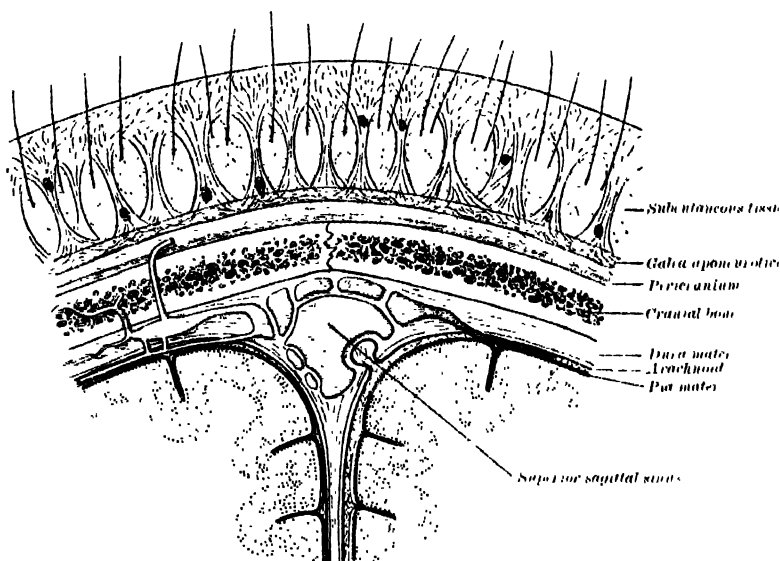
Submaxillary gland.—On either side of the neck the superficial portion of the submaxillary gland, as it lies partly under cover of the body of the mandible, can be palpated.

SURFACE MARKINGS OF SPECIAL REGIONS OF HEAD AND NECK

THE CRANIUM

Scalp.—The soft parts covering the upper surface of the skull form the scalp and comprise the following layers (fig. 1120): (1) skin, (2) subcutaneous tissue, (3) Occipitalis, Frontalis, and galea aponeurotica, (4) subaponeurotic tissue, (5) pericranium. The subcutaneous tissue consists of a close meshwork of fibres, the meshes of which contain fatty tissue; the fibres bind the skin and galea aponeurotica firmly together, so that when the Occipitalis or the Frontalis is in action the skin

FIG. 1120.—Diagrammatic section of scalp.



moves with the aponeurosis. The subaponeurotic tissue is much looser in texture, and permits the movement of the galea aponeurotica over the underlying pericranium.

Bony landmarks (fig. 1117).—In addition to the bony points already described, which can be determined by palpation, the following are utilised for surface markings:

Asterion.—The point of meeting of the lambdoidal, masto-occipital, and masto-parietal sutures; it lies 4 cm. behind and 12 mm. above the level of the auricular point.

Auricular point.—The centre of the orifice of the external acoustic meatus.

Bregma.—The meeting-point of the coronal and sagittal sutures; it lies at the point of intersection of the middle line of the scalp with a line drawn vertically upwards through the pre auricular point.

Lambda.—The point of meeting of the lambdoidal and sagittal sutures; it is in the middle line about 6.5 cm. above the inion.

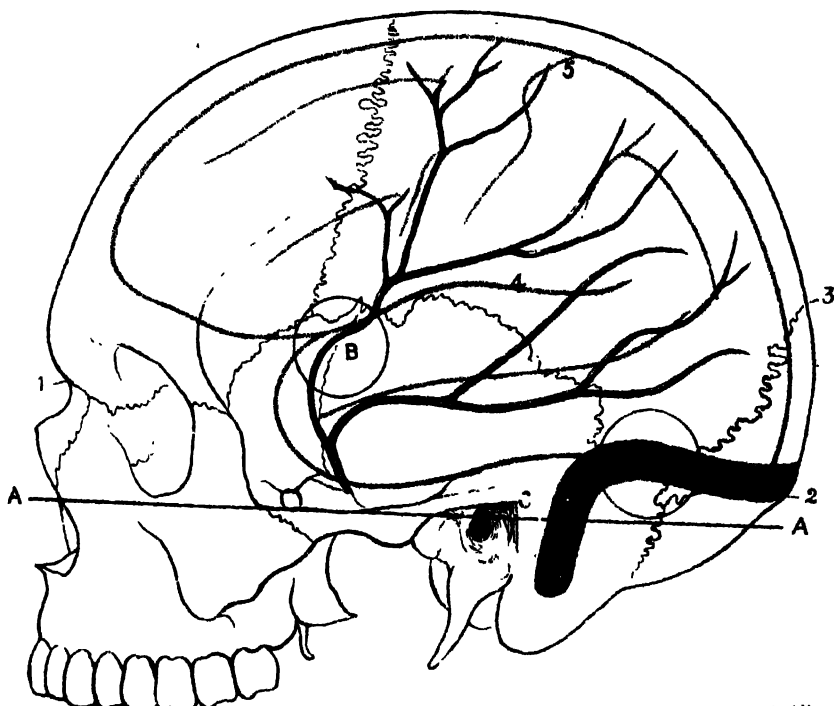
Pre-auricular point.—A point on the posterior root of the zygomatic arch immediately in front of the orifice of the external acoustic meatus.

Pterion.—The point where the great wing of the sphenoid joins the sphenoidal angle of the parietal; it is situated 35 mm. behind, and 12 mm. above, the level of the frontozygomatic suture.

A line passing through the inferior margin of the orbit and the auricular point is known as *Reid's base-line*. The *lambdoidal suture* is indicated by the upper two-thirds of a line uniting the lambda to the tips of the mastoid processes. The *sagittal suture* is in the line joining the lambda to the bregma. The position of the *coronal suture* is represented by a line connecting the bregma with the centres of the zygomatic arches.

of the third with the fourth part (reckoning from the front) draw a line to the frontozygomatic suture; from the junction of the first with the second part a line to the auricular point. These two lines intersect at the Sylvian point, and the portion of the first line behind this point overlies the posterior ramus of the lateral cerebral fissure. The position of the posterior ramus can also be obtained by joining the Sylvian point to one 2 cm. below the summit of the parietal tuberosity. The anterior ascending ramus is marked by drawing a line upwards at right angles to the line of the posterior ramus for 2 cm., and the anterior horizontal ramus by a line of the same length drawn horizontally forwards—both from the Sylvian point. To define the *central sulcus* (fissure of Rolando) two points are taken; one 1.25 cm. behind the centre of the line joining the nasion andinion; the other

FIG. 1122.—Relations of the brain and middle meningeal artery to the surface of the skull.



1. Nasion. 2. Inion. 3. Lambda. 4. Lateral cerebral fissure. 5. Central sulcus. AA. Reid's base-line. B. Point for trephining over the anterior branch of the middle meningeal artery. C. Supra-mental triangle. D. Sigmoid bend of the transverse sinus. E. Point for trephining over the straight portion of the transverse sinus, exposing dura mater of both cerebrum and cerebellum. The outline of the cerebral hemisphere is indicated in blue; the course of middle meningeal artery in red.

at the intersection of the line of the posterior ramus of the lateral cerebral fissure with a line through the pre-auricular point at right angles to Reid's base-line. The upper 9 cm. of the line joining these two points overlies the central sulcus and forms an angle, opening forwards, of about 70° with the middle line of the scalp. An alternative method is to draw two perpendicular lines from Reid's base-line to the top of the head; one from the pre-auricular point and the other from the posterior border of the root of the mastoid process. A line from the upper end of the posterior line to the point where the anterior intersects the line of the posterior ramus of the lateral fissure indicates the position of the central sulcus. The *precentral* and *postcentral sulci* are nearly parallel with the central sulcus, and are situated about 15 mm. in front of, and behind, it respectively. The *superior frontal sulcus* is indicated by a line drawn from the junction of the upper with the middle third of the precentral sulcus, in a direction parallel with the longitudinal sulcus, to a point midway between the middle line of the forehead and the temporal line, 4 cm. above the supraorbital notch. The *inferior frontal sulcus* begins at the junction of the middle with the lower third of the precentral sulcus, and follows the course of the superior temporal line.

The horizontal limb of the *intraparietal sulcus* begins at the junction of the lower with the middle third of the postcentral sulcus and curves backwards parallel to the longitudinal fissure, midway between it and the parietal tuberosity; it then curves downwards to end midway between the lambda and the parietal tuberosity. The external part of the *parieto-occipital fissure* runs lateralwards at right angles to the longitudinal fissure for about 2.5 cm. from a point 5 mm. in front of the lambda. If the line of the posterior ramus of the lateral cerebral fissure be continued back to the longitudinal fissure, the last 2.5 cm. of it will indicate the position of the parieto-occipital fissure.

The *lateral ventricle* may be circumscribed by a quadrilateral figure. The upper limit is a horizontal line 5 cm. above the zygomatic arch; this defines the roof of the ventricle. The lower limit is a horizontal line 1 cm. above the zygomatic arch; it indicates the level of the end of the inferior cornu. Two vertical lines, one through the junction of the anterior with the middle third of the zygomatic arch, and the other 5 cm. behind the tip of the mastoid process, indicate the extent of the anterior cornu in front and the posterior cornu behind.

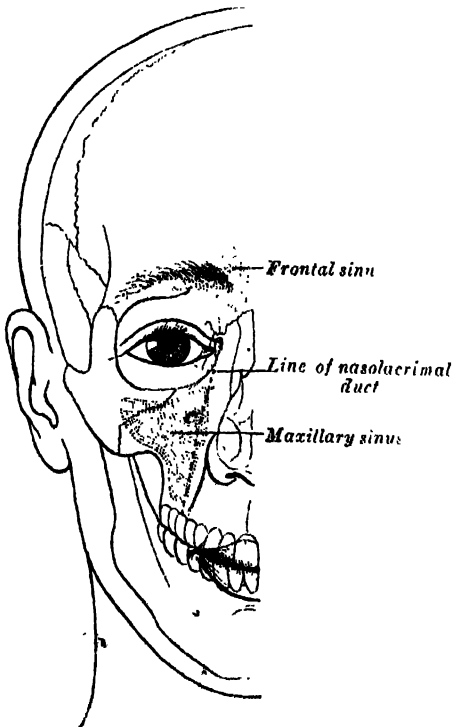
Vessels.—The anterior division of the *middle meningeal artery* crosses the inner surface of the sphenoidal angle of the parietal bone at a point 4 cm. behind the frontozygomatic suture and 4.5 cm. above the zygomatic arch. The posterior division can be reached 2.5 cm. above the auricular point.

The position of the *transverse sinus* is obtained by taking two lines: the first from the inion to a point 2.5 cm. behind the auricular point; the second from the anterior end of the first to the tip of the mastoid process. The second line corresponds roughly to that of the reflection of the skin from the cranial surface of the auricula, and its upper two-thirds represents the sigmoid part of the sinus. The first part of the sinus has a slight upward convexity, and its highest point is about 4 cm. behind and 1 cm. above the level of the auricular point. The width of the sinus is about 1 cm.

THE FACE

Air-sinuses (fig. 1123).—The frontal and maxillary sinuses vary so greatly in form and size that their surface markings must be regarded as only approximate.

FIG. 1123.—Outline of bones of face, showing position of frontal and maxillary sinuses.



To mark out the position of the *frontal sinus* three points are taken: one at the nasion, a second in the middle line 3 cm. above the nasion, and a third at the junction of the lateral with the intermediate third of the supraorbital margin. By joining these a triangular field is described which overlies the greater part of the sinus. The outline of the *maxillary sinus* is irregularly quadrilateral and is obtained by joining up the following points: (1) the lacrimal tubercle, (2) a point on the zygomatic bone at the junction of the inferior with the lateral margin of the orbit, (3) and (4) points on the alveolar process above the last molar and the second premolar teeth respectively.

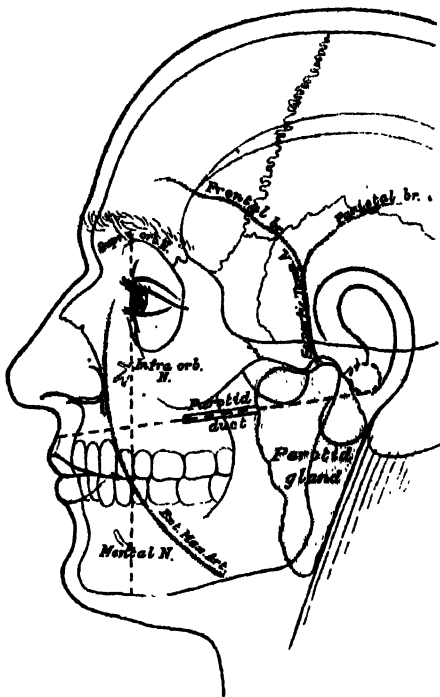
External maxillary artery.—The course of this artery on the face may be indicated by a line starting from the lower border of the mandible at the anterior margin of the Masseter, and running at first forwards and upwards to a point 1 cm. laterally to the angle of the mouth, thence to the ala of the nose and upwards to the medial commissure of the eye (fig. 1124).

Trigeminal nerve.—The supratrochlear nerve crosses the supraorbital margin about 1 cm. from the middle line. The supraorbital, infraorbital, and mental branches of the trigeminal nerve emerge from the corresponding foramina on the face (fig. 1124). The supraorbital foramen is situated at the junction of the medial with the intermediate third of the supraorbital margin. A line drawn from this foramen to the lower border of the mandible, through the interval between the lower premolar teeth, passes over the infraorbital and mental foramina: the former lies about 1 cm. below the margin of the orbit, while the latter varies in position according to the age of the individual; in the adult it is midway between the upper and lower borders of the mandible, in the child it is nearer the lower border, while in the edentulous jaw of old age it is close to the upper margin.

The position of the sphenopalatine ganglion is indicated from the side by a point on the upper border of the zygomatic arch, 6 mm. from the temporal border of the zygomatic bone. The foramen ovale, which is the guide to the semilunar ganglion, lies opposite the anterior border of the neck of the mandible.

Parotid gland (fig. 1124). -- The upper border of the parotid gland corresponds to the posterior two-thirds of the lower border of the zygomatic arch; the posterior border to the front of the external acoustic meatus, the mastoid process, and the anterior border of Sternocleidomastoideus. The inferior border is indicated by a line from the tip of the mastoid process to the junction of the body and greater cornu of the hyoid bone. In front, the anterior border extends for a variable distance on the superficial surface of the Masseter. The surface marking for the *parotid duct* is a line drawn across the face about a finger's breadth below the zygomatic arch, i.e. from the lower margin of the concha to midway between the red margin of the lip and the ala of the nose; the duct ends opposite the second upper molar tooth and measures about 5 cm. in length.

FIG. 1124.—Outline of side of face, showing chief surface markings.



THE NOSE

The outlines of the nasal bones and the cartilages forming the external nose can be easily felt. The mobile portion of the nasal septum, formed by the medial crura of the greater alar cartilages and the skin, is easily distinguished between the nares. When the head is tilted back and a speculum introduced through one naris, the floor of the nasal cavity, the lower part of the nasal septum, and the anterior ends of the middle and inferior nasal conchæ can be examined. The opening of the nasolacrimal duct, which lies under cover of the front of the inferior nasal concha, is situated about 2.5 cm. behind the naris and 2 cm. above the floor of the nasal cavity.

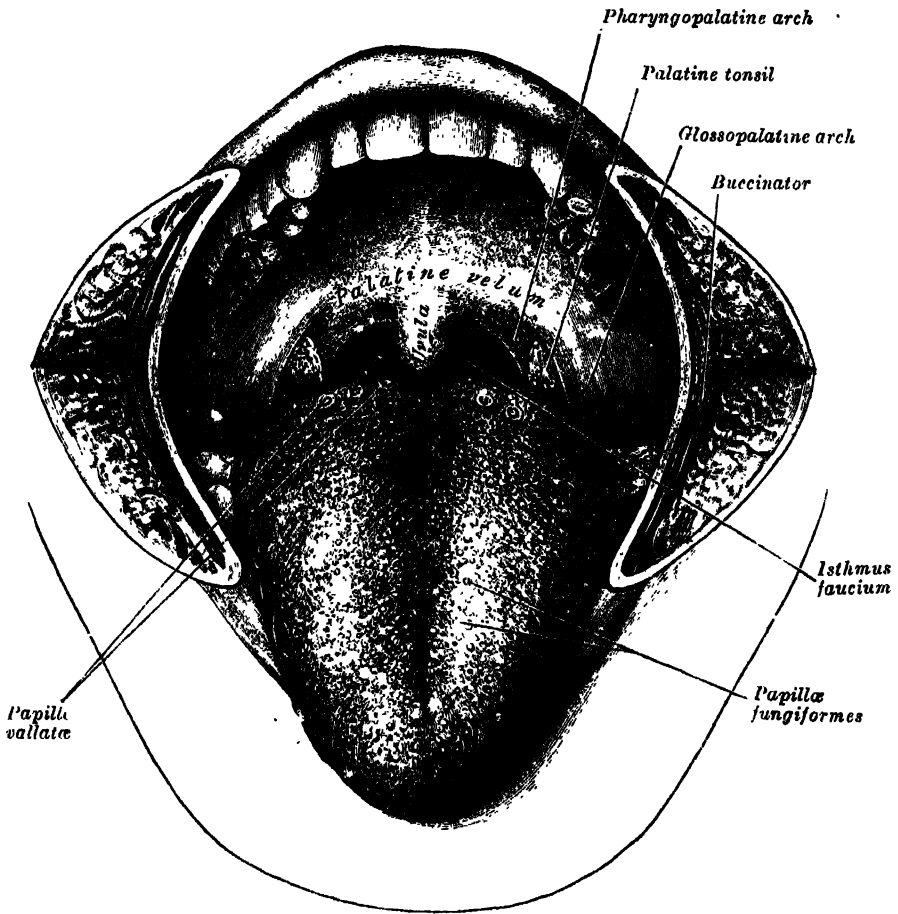
THE MOUTH

The orifice of the mouth is bounded by the lips, and its angles usually correspond to the lateral borders of the canine teeth. In the middle of the outer surface of the upper lip is a shallow groove—the philtrum. When the lips are everted, a small fold of mucous membrane, termed the frenulum, is seen in the middle line of each, passing from the lip to the gum. By pulling the angle of the mouth outwards the mucous

membrane of the cheek can be inspected, and on this, opposite the second upper molar tooth, is the little papilla which marks the orifice of the parotid duct.

The upper surface of the tongue (fig. 1125) is convex and marked in the middle line by a shallow sulcus; its anterior two-thirds are rough and studded with papillæ; its posterior third is smoother and contains many muciparous glands and lymph-follicles; it is much more sensitive than the anterior papillary part. These two parts are separated by a V-shaped furrow, the *sulcus terminalis*, which is situated immediately behind the *papillæ vallatæ*.

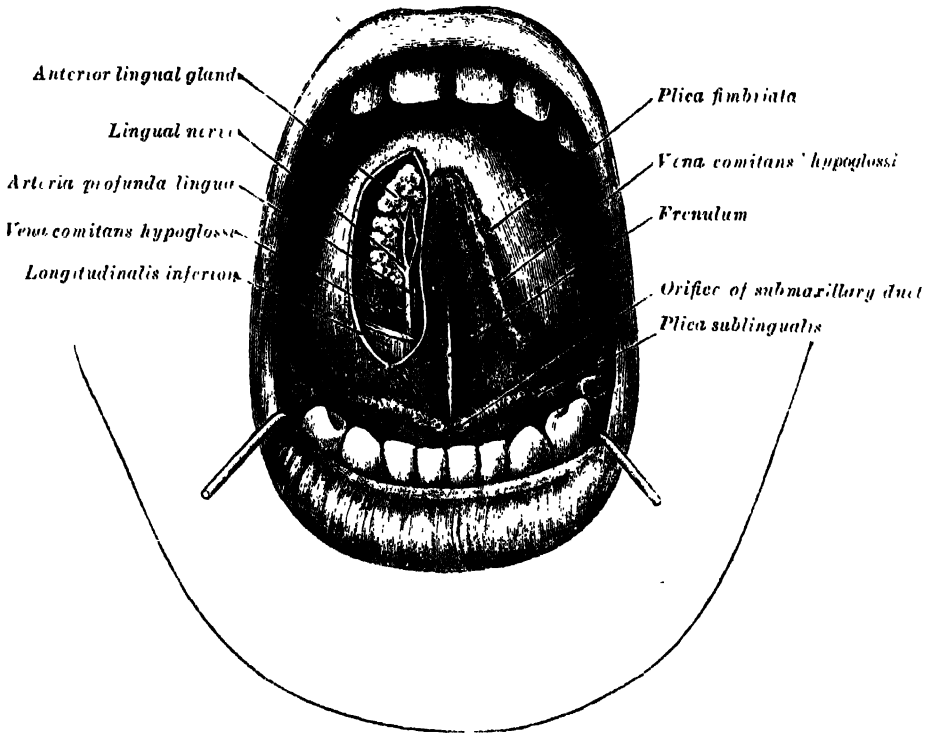
FIG. 1125.—The mouth-cavity. The cheeks have been slit transversely and the tongue pulled forwards.



The mucous membrane on the under surface of the tongue (fig. 1126) is smooth and devoid of papillæ. In the middle line it extends to the floor of the mouth as a fold—the *frenulum*—the free edge of which runs forwards to the symphysis menti. The *ranine veins* are seen immediately beneath the mucous membrane on either side of the *frenulum*. On either side of the attachment of the *frenulum* to the floor of the mouth is a *papilla* on which the slit-like orifice of the *submaxillary duct* is seen. Running backwards and lateralwards from the orifice of the *submaxillary duct* is the *plica sublingualis*, produced by the upward projection of the *sublingual gland* which lies immediately beneath the mucous membrane. The *plica lingualis* serves also to indicate the lines of the *submaxillary duct* and *lingual nerve*; they lie on the medial side of the gland. At the back of the mouth is the *isthmus faucium*, bounded above by the *palatine velum*, from the free margin of which the *uvula* projects downwards in the middle line. On either side of the *isthmus* are the two *palatine arches*, the anterior formed by the *Glossopalatinus*

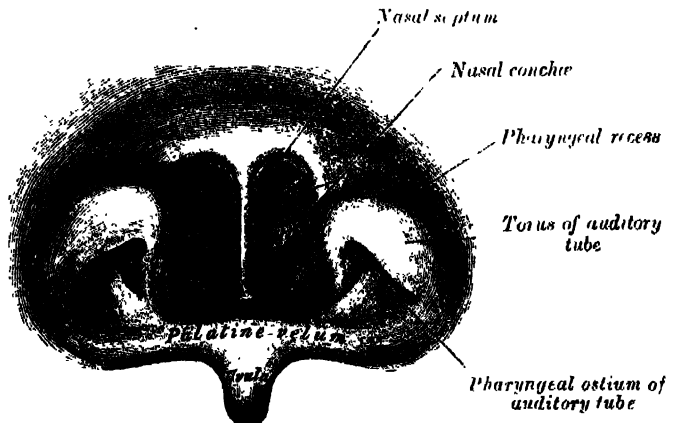
and the posterior by the Pharyngopalatinus. Between the two arches of either side is the palatine tonsil, with the small supratonsillar recess above it; the position

FIG. 1126.—The mouth cavity. The apex of the tongue is turned upwards, and on the right side a superficial dissection of its under surface has been made.



of the tonsil corresponds to the angle of the mandible. When the mouth is opened widely, a tense band--the pterygomandibular raphe--can be seen and felt laterally to the glossopalatine arch. Its lower end is attached to the mandible behind the last molar tooth, and immediately below and in front of this attachment the

FIG. 1127.—Front of nasal part of pharynx, as seen with the laryngoscope.

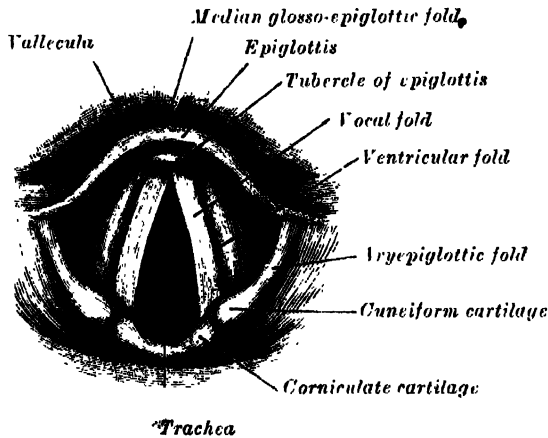


lingual nerve can be felt; the upper end of the raphe is fixed to the pterygoid hamulus. About 1 cm. anterior to the hamulus and 1 cm. medial to the third

upper molar tooth is the greater palatine foramen through which the greater palatine vessels and the anterior palatine nerve emerge. Behind the third upper molar tooth the coronoid process of the mandible is palpable.

By tilting the head well back a portion of the posterior pharyngeal wall, corresponding to the level of the second and third cervical vertebræ, can be seen

FIG. 1128.—Laryngoscopic view of interior of larynx.

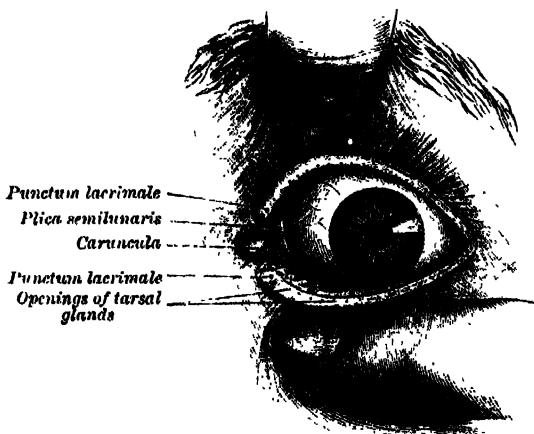


through the isthmus faucium. On introducing the finger the anterior surfaces of the upper cervical vertebræ can be felt through the thin muscular wall of the pharynx; if the finger be hooked round the palatine velum, the choana, the posterior ends of the middle and inferior nasal conchæ, and the pharyngeal ostia of the auditory (Eustachian) tubes can be distinguished. The level of the choana is that of the atlas, while the palatine velum is opposite the body of the epistropheus.

With the laryngoscope the following structures can be seen. In the nasal part of the pharynx (fig. 1127), the choana, the nasal septum and conchæ, and the pharyngeal ostia of the auditory tubes can be examined. Farther down are the base of the tongue, the anterior surface of the epiglottis with the medial and lateral glosso-epiglottic folds bounding the valleculæ, and the pyriform sinuses. Beyond these is the entrance to the larynx, bounded on either side by the aryepiglottic folds,

in each of which are two rounded eminences corresponding to the corniculate and cuneiform cartilages. Within the larynx (fig. 1128) on either side are the ventricular and vocal folds (false and true vocal cords) with the ventricle of the larynx between them. Still deeper, the cricoid cartilage and the anterior parts of some of the cartilaginous rings of the trachea are visible, and sometimes, during deep inspiration, the bifurcation of the trachea.

FIG. 1129.—Front of left eye with eyelids separated to show structures at medial commissure.



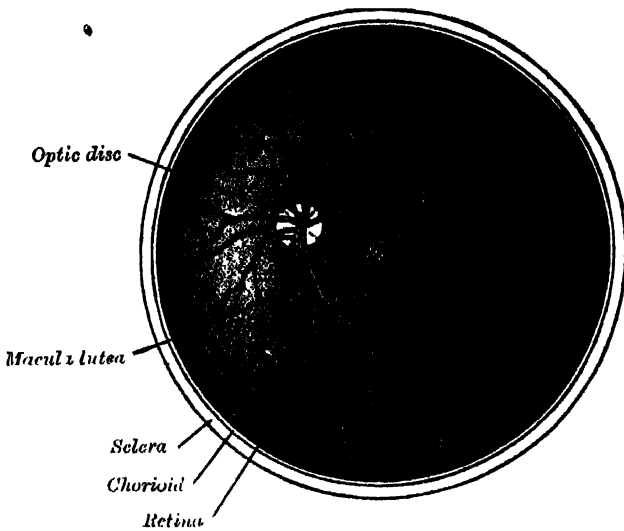
THE EYE

The palpebral fissure is elliptical in shape, and varies in form and size in different individuals and in different races of mankind; normally it is oblique, in a direction upwards and lateralwards, so that the lateral commissure is on a slightly higher level than the medial. When the eyes are

directed forwards as in ordinary vision the superior part of the cornea is covered by the upper eyelid and its inferior margin is on a level with the free margin of the lower eyelid.

At the medial commissure (fig. 1129) are the *caruncula lacrimalis* and the *plica semilunaris*. When the lids are everted, the tarsal glands appear as a series of

FIG. 1130.—The interior of the posterior half of the left eyeball.



vertical parallel rows of light yellow granules. On the margins of the lids about 5 mm. from the medial commissure are the *puncta lacrimalia*; in the natural condition they are in contact with the conjunctiva of the bulb of the eye, so that it is necessary to evert the eyelids to expose them. The lacrimal sac lies immediately above and medially to a small tubercle which can be plainly felt on the inner part of the lower margin of the orbit. If the eyelids be drawn lateralwards a prominent cord, the medial palpebral ligament, can be felt beneath the tightened skin at the medial commissure; it crosses in front and a little above the middle of the lacrimal sac, and forms a useful guide to it. The direction of the nasolacrimal duct is indicated by a line from the lacrimal sac to the first upper molar tooth; the length of the duct is about 18 mm.

On looking into the eye, the iris with its opening, the pupil, and the front of the lens can be examined, but for investigation of the retina an ophthalmoscope is necessary. With this instrument the lens, the vessels of the retina, the optic disc, and the macula lutea can all be inspected (fig. 1130).

On the lateral surface of the nasal part of the frontal bone the pulley of the *Obliquus superior* can be easily reached by pushing the finger backwards along the roof of the orbit; the tendon of the muscle can be traced for a short distance backwards and lateralwards from the pulley.

THE EAR

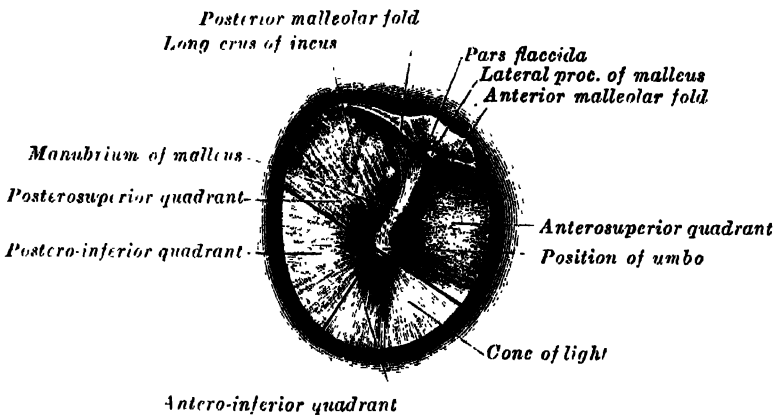
The various prominences and fossæ of the auricula (pp. 978 to 981) are visible (fig. 1131). The orifice of the external acoustic meatus is exposed by drawing the tragus forwards; at the orifice are a few short crisp hairs which serve to prevent the entrance of dust or of small

FIG. 1131.—The auricula or pinna. Lateral surface.



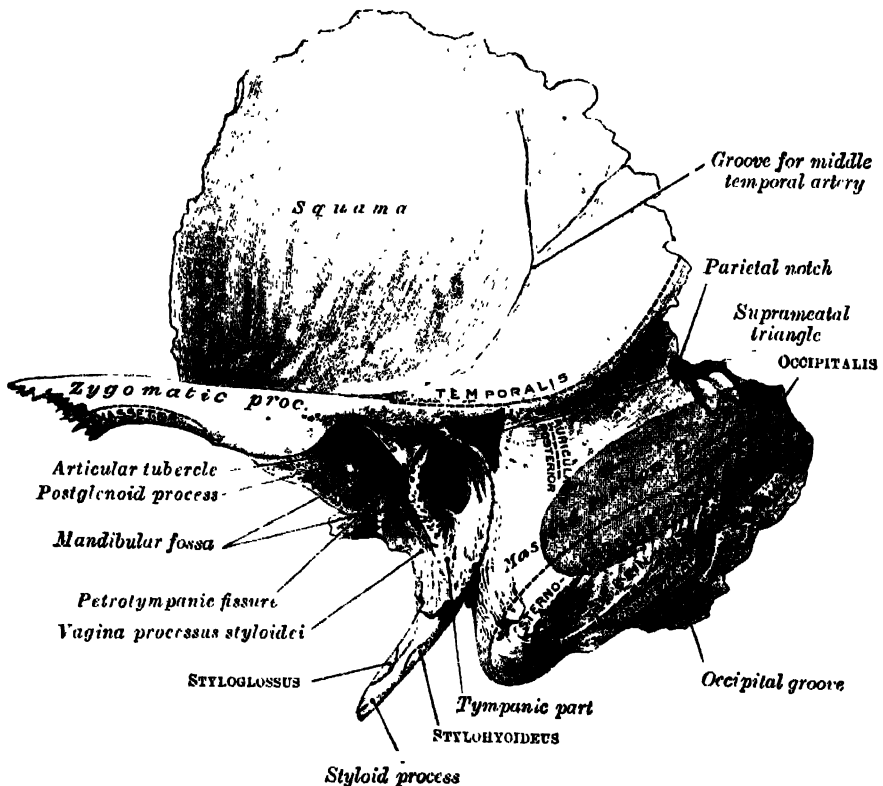
insects; beyond this the secretion of the ceruminous glands serves to catch any small particles which may find their way into the meatus. The interior of the

FIG. 1132.—The right tympanic membrane, as seen through a speculum.



meatus can be examined through a speculum. At the junction of its bony and cartilaginous portions an obtuse angle is formed which projects into the antero-inferior wall and produces a narrowing of the lumen. The cartilaginous part, however, is connected to the bony part by fibrous tissue only, which renders the

FIG. 1133.—Left temporal bone showing surface markings for the tympanic antrum (red), transverse sinus (blue), and facial nerve (yellow).



outer portion of the meatus very movable, and therefore by drawing the auricula upwards, backwards, and slightly outwards, the canal is rendered almost straight.

In children the meatus is very short, and this should be remembered in introducing a speculum.

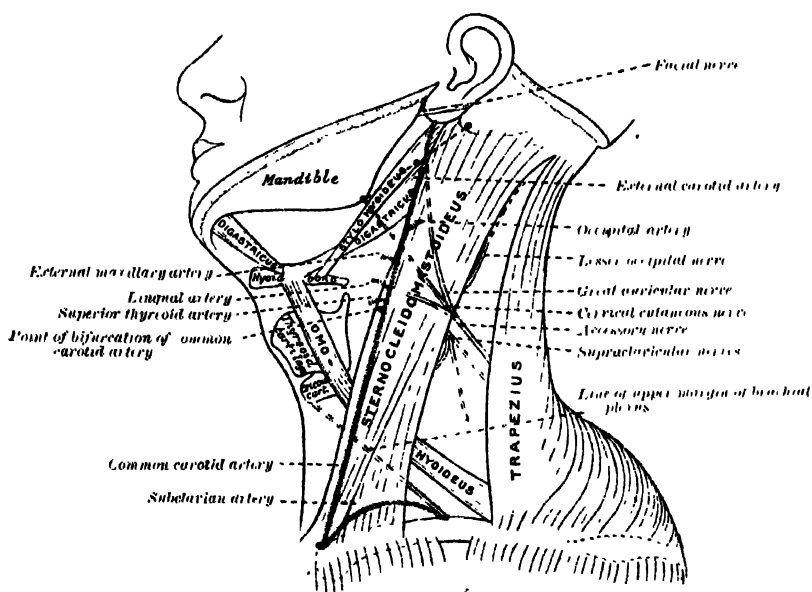
Through the speculum the greater part of the tympanic membrane (fig. 1132) is visible. It is a pearly-grey, slightly glistening membrane; in the adult it is placed obliquely so as to form with the floor and with the anterior wall of the meatus an angle of about fifty-five degrees; at birth it is more horizontal and situated in almost the same plane as the base of the skull. The membrane is concave outwards, and the point of deepest concavity is a little below the centre. Running upwards and slightly forwards from this point is a reddish-yellow streak produced by the manubrium of the malleus. This streak ends above near the roof of the meatus at a small white rounded prominence which is caused by the lateral process of the malleus projecting against the membrane. The anterior and posterior malleolar folds extend from the prominence to the circumference of the membrane and form the lower boundary of the pars flaccida of the membrane. Behind the streak caused by the manubrium of the malleus a shorter and fainter streak can sometimes be distinguished; this is the long crus of the incus. A narrow triangular patch extending downwards and forwards from the lower end of the manubrium mallei reflects the light more brightly than any other part, and is usually described as the cone of light.

Tympanic antrum.—The site of the tympanic antrum is indicated by the supra-meatal triangle (fig. 1133) which is bounded above by the posterior root of the zygomatic arch, behind by a vertical line from the posterior border of the bony external acoustic meatus, in front and below by the upper margin of the meatus.

THE NECK (fig 1134)

Muscles.—The posterior belly of the *Digastricus* is marked out by a line from the tip of the mastoid process to the junction of the greater cornu and body of the hyoid bone; a line from this latter point to one just laterally to the symphysis menti

FIG. 1134.—Side of neck, showing chief surface markings.



indicates the position of the anterior belly. The line of the *Omo-hyoideus* begins at the lower border of the body of the hyoid bone, runs downwards and lateralwards to cross the *Sterno-cleido-mastoideus* at the level of the cricoid cartilage, and then runs more horizontally to the acromial end of the clavicle.

Arteries.—The position of the *common carotid* artery in the neck is indicated by a line drawn from the upper part of the sternal end of the clavicle to a point midway between the tip of the mastoid process and the angle of the mandible.

From the clavicle to the upper border of the thyroid cartilage this line overlies the common carotid artery, beyond this it is over the external carotid artery. The external carotid artery may be otherwise marked out by the upper part of a line, arching slightly forwards, from the side of the cricoid cartilage to the front of the orifice of the external acoustic meatus.

The points of origin of the main branches of the external carotid artery are related to the tip of the greater cornu of the hyoid bone as follows: (1) the *superior thyroid*, just below it; (2) the *lingual*, on a level with it; (3) the *external maxillary* (facial) and (4) the *occipital*, a little above and behind it.

The *subclavian* artery is indicated on the surface by a curved line, convex upwards, from the sternoclavicular articulation to the middle of the clavicle. The highest point of the convexity is about 2 cm. above the clavicle.

Veins. The surface marking for the *internal jugular* vein is parallel with and slightly lateral to that for the common carotid artery. The position of the *external jugular* vein is marked by a line from the angle of the mandible to the middle of the clavicle. A point on this line about 4 cm. above the clavicle indicates the spot where the vein pierces the deep fascia. The line of the *anterior jugular* vein begins close to the symphysis menti, runs downwards parallel with and a little to one side of the middle line, and, at a short distance above the jugular notch, turns lateralwards to the external jugular.

Nerves. The *facial* nerve at its exit from the stylomastoid foramen is situated, in the adult, about 2.5 cm. from the surface, opposite the middle of the anterior border of the mastoid process; a horizontal line from this point to the ramus of the mandible overlies the stem of the nerve. In the infant there is no mastoid process, and the foramen is placed superficially just behind the meatus. To mark the course of the *accessory* nerve a line is drawn from a point midway between the angle of the mandible and the tip of the mastoid process to a point on the anterior border of the Sternocleidomastoideus 4 cm. below the apex of the mastoid process, or to the midpoint of the posterior border of the muscle; the line is continued across the posterior triangle of the neck to the Trapezius.

The cutaneous branches of the cervical plexus emerge from beneath the posterior border of the Sternocleidomastoideus and may be indicated as follows: the *lesser occipital* appears just above the midpoint of the border and ascends along it to the scalp; the *great auricular* and *cervical cutaneous* start from the middle of the border, the former running upwards towards the lobule of the auricle, the latter crossing the Sternocleidomastoideus at right angles to its long axis; the *supraclavicular* nerves emerge just below the middle of the posterior border and run down over the clavicle. The *phrenic* nerve begins at the level of the middle of the thyroid cartilage and runs behind the clavicle about midway between the anterior and posterior borders of the Sternocleidomastoideus.

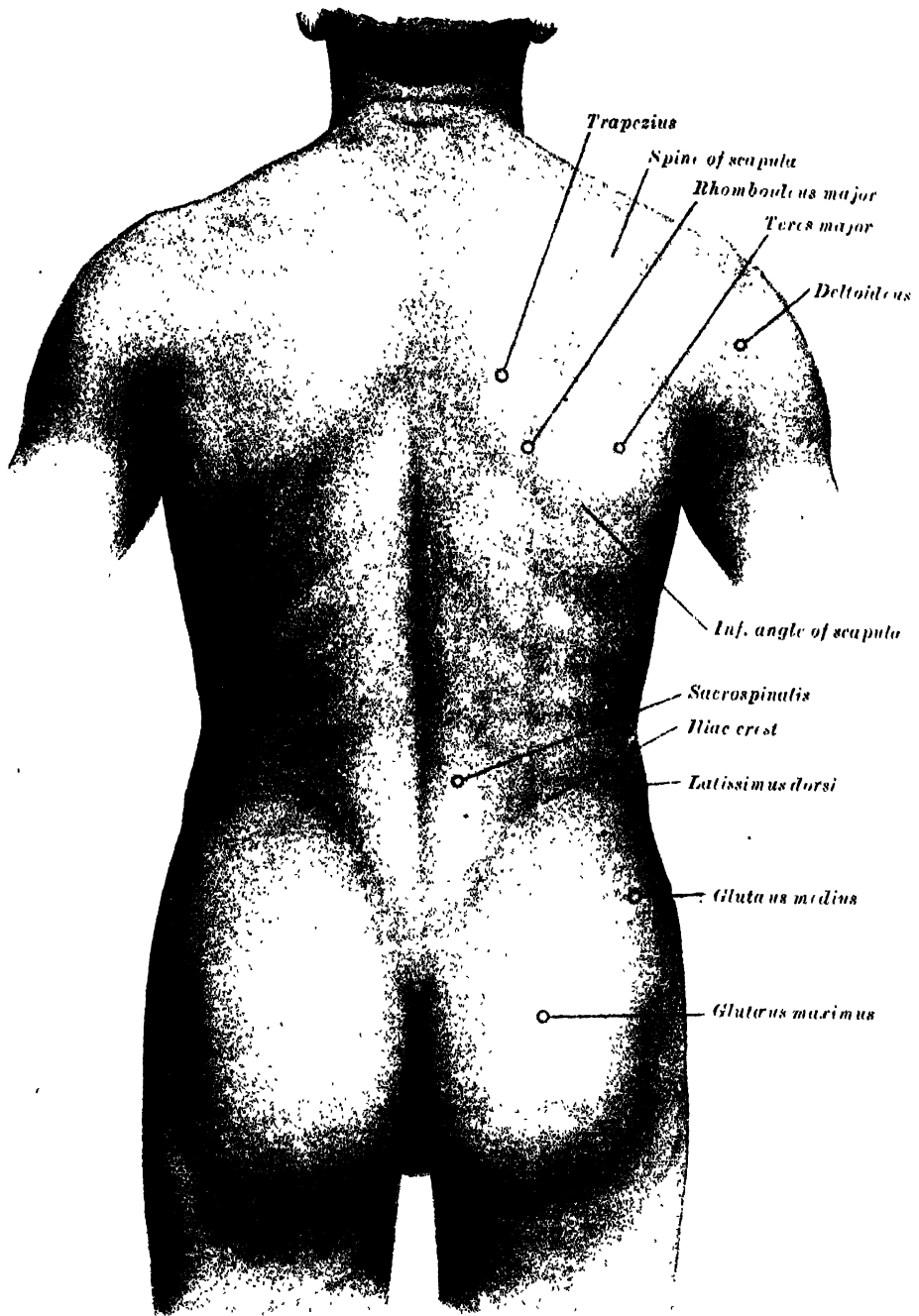
The upper border of the *brachial plexus* is indicated by a line from the side of the cricoid cartilage to the middle of the clavicle.

SURFACE ANATOMY OF THE BACK

Bones.—The only subcutaneous parts of the vertebral column are the apices of the spinous processes. These are distinguishable at the bottom of a furrow which runs down the middle line of the back from the external occipital protuberance to the middle of the sacrum. In the *cervical region* the furrow is broad and ends below in a conspicuous projection caused by the spinous processes of the seventh cervical and first thoracic vertebrae. Above this, the spinous process of the sixth cervical vertebra sometimes forms a projection; the other cervical spinous processes are sunken, but that of the epistropheus can be felt. In the *thoracic region* the furrow is shallow and during stooping disappears, and then the spinous processes become more or less visible; the markings produced by them are small and close together. In the *lumbar region* the furrow is deep and the situations of the spinous processes are frequently indicated by little pits, especially when the muscles in the loins are well developed. In the *sacral region* the furrow is shallow and flattened, and ends below at the most prominent part of the dorsal surface of the sacrum, i.e. the spinous process of the third sacral vertebra. At the bottom of the sacral furrow the irregular dorsal surface of the sacrum may be felt, and below this, in the deep groove running to the anus, the coccyx.

Muscles.—The deep muscles of the back are so covered by those of the upper extremity (fig. 1135) that they have very little influence on surface form. The *Splenii* by their divergence serve to broaden out the upper part of the back of the

FIG. 1135.—Surface anatomy of the back.

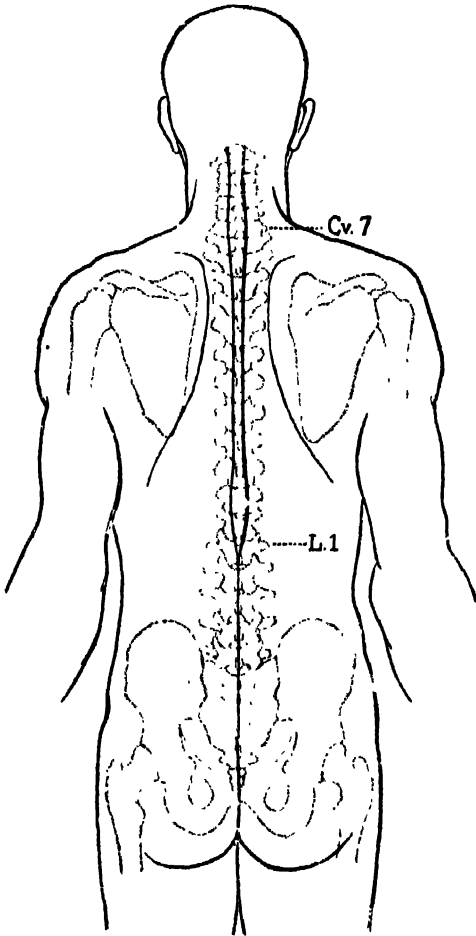


neck and produce a fulness in this situation. In the loin the *Sacrospinales*, bound down by the lumbodorsal fascia, form rounded vertical eminences which determine the depth of the spinal furrow and taper below to a point on the dorsal surface of the sacrum. The continuations of the *Sacrospinales* in the lower thoracic region form flattened planes which are gradually lost on passing upwards.

SURFACE MARKINGS OF THE BACK

Bony landmarks.—In order to identify any particular spinous process it is customary to count from the prominence caused by the seventh cervical and first thoracic; of these the latter is the more prominent, although the seventh cervical is known as the *vertebra prominens*. The root of the spine of the scapula is on

FIG. 1136.—Diagram showing the relation of the medulla spinalis to the dorsal surface of the trunk. The bones are outlined in red.



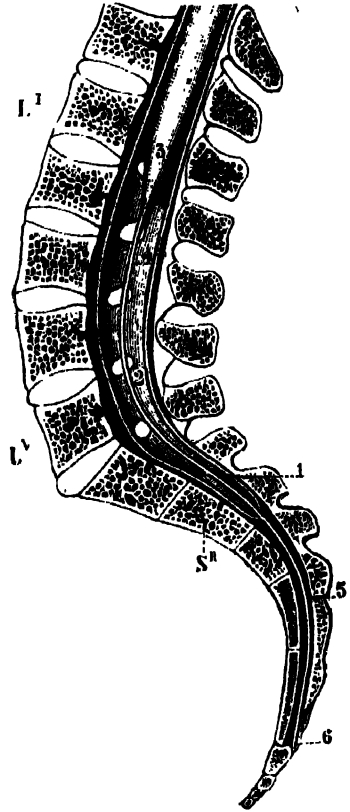
a level with the tip of the spinous process of the third thoracic vertebra, and the inferior angle with that of the seventh.

The highest point of the iliac crest is on a level with the spinous process of the fourth lumbar vertebra, and the posterior superior iliac spine with that of the second sacral vertebra.

Medulla spinalis.—The position of the lower end of the medulla spinalis varies slightly with the movements of the vertebral column, but, in the adult, in the upright posture it is usually at the level of the spinous process of the second lumbar vertebra (fig. 1136); at birth it is at the level of the fourth.

The *subdural* and *subarachnoid cavities* end below opposite the spinous process of the third sacral vertebra (fig. 1137).

FIG. 1137.—Sagittal section of lower part of vertebral canal to show the lower ends of the medulla spinalis and subarachnoid cavity and the filum terminale. (Testut.)

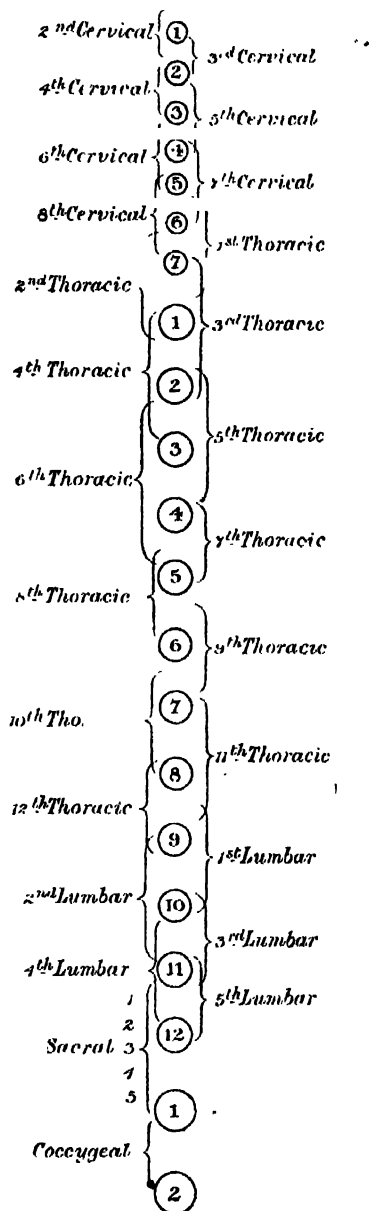


L^I, L^V. First and fifth lumbar vertebrae. S^{II}. Second sacral vertebra. 1. Dura mater. 2. Lower part of subarachnoid cavity. 3. Lower extremity of medulla spinalis. 4. Filum terminale internum. 5. Filum terminale externum. 6. Attachment of filum terminale to first segment of coccyx.

Spinal nerves (fig. 1138).—The following table, after Macalister, shows the relations which the places of attachment of the nerves to the medulla spinalis bear to the bodies and spinous processes of the vertebrae :—

Level of body of	No. of nerve.	Level of tip of spine of
C. 1	C. 1	...
2	(2)	...
3	(3)	1 C.
4	4	2
5	5	3
6	6	4
...	7	5
7	8	6
T. 1	T. 1	7
2	2	1 T.
3	3	...
4	4	2
5	5	3
6	6	4
7	7	5
8	8	6
9	9	7
10	10	8
...	11	9
11	12	10
...	L. 1	11
12	(2)	...
...	(3)	...
...	(4)	12
...	(5)	...
L. 1	S. 1	...
...	(2)	...
...	(3)	...
...	(4)	1 L.
...	(5)	...
L. 2	C. 1	...
...

FIG. 1138.—Scheme showing the relations of the regions of attachment of the spinal nerves to the vertebral spinous processes. (After Reid.)



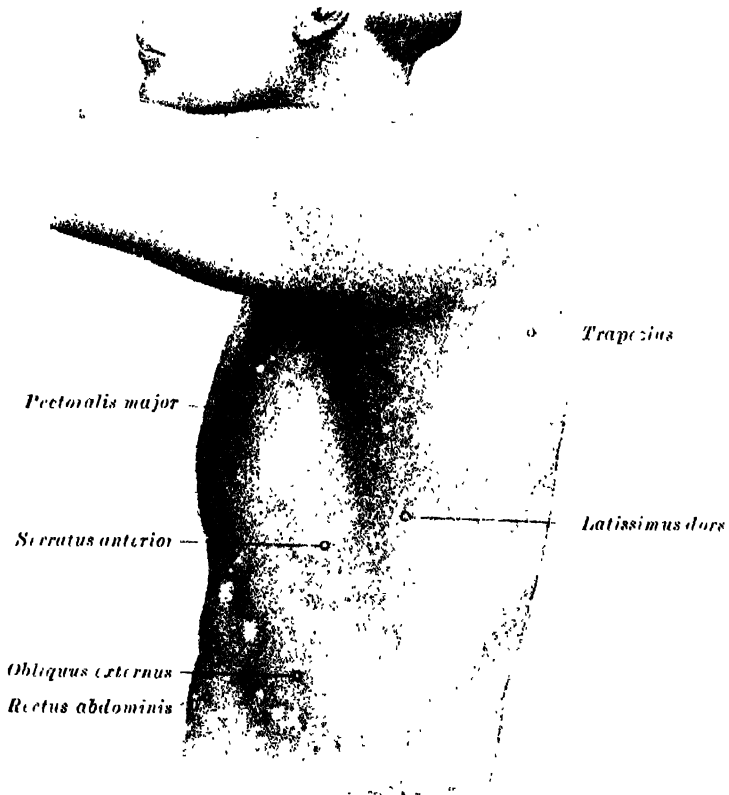
SURFACE ANATOMY OF THE THORAX

Bones.—The skeleton of the thorax is covered to a considerable extent by muscles, so that in the strongly developed muscular subject it is for the most part concealed. In thin persons the ribs, especially in the lower and lateral regions, stand out as prominent ridges with the sunken intercostal spaces between them.

In the middle line, in front, the anterior surface of the *sternum* can be felt throughout its entire length at the bottom of the sternal furrow, between the *Pectorales majores*. These muscles overlap the anterior surface somewhat, so

that the whole width of the sternum is not subcutaneous, and this overlapping is greatest opposite the middle of the bone; the furrow, therefore, is wide at its upper and lower parts but narrow in the middle. At the upper border of the manubrium sterni is the *jugular notch*: the lateral parts of this notch are obscured by the tendinous origins of the *Sternocleidomastoidei*, which appear as oblique cords narrowing and deepening the notch. At the junction of the manubrium and body is a well-defined transverse ridge, the *sternal angle* (*angulus Ludovici*). From the middle of the sternum the sternal furrow widens and ends at the junction of the body of the sternum with the xiphoid process. Immediately below this

FIG. 1139.—The left side of the thorax.



is the *infrasternal notch*; between the sternal ends of the seventh costal cartilages, and below the notch, is a triangular depression, the *epigastric fossa*, in which the *xiphoid process* can be felt.

On either side of the sternum the costal cartilages and ribs on the front of the thorax are partially obscured by the *Pectoralis major*, through which, however, they can be felt as ridges with yielding intervals between them corresponding to the intercostal spaces. The second space is the widest, the third and fourth are somewhat narrower, and the others, with the exception of the last two, are comparatively narrow.

Below the lower border of the *Pectoralis major* on the front of the chest, the broad flat outlines of the ribs, and the more rounded outlines of the costal cartilages, are often visible. The lower boundary of the front of the thorax is most plainly seen when the body is bent backwards; it is formed by the xiphoid process, the cartilages of the seventh, eighth, ninth, and tenth ribs, and the ends of the cartilages of the eleventh and twelfth ribs.

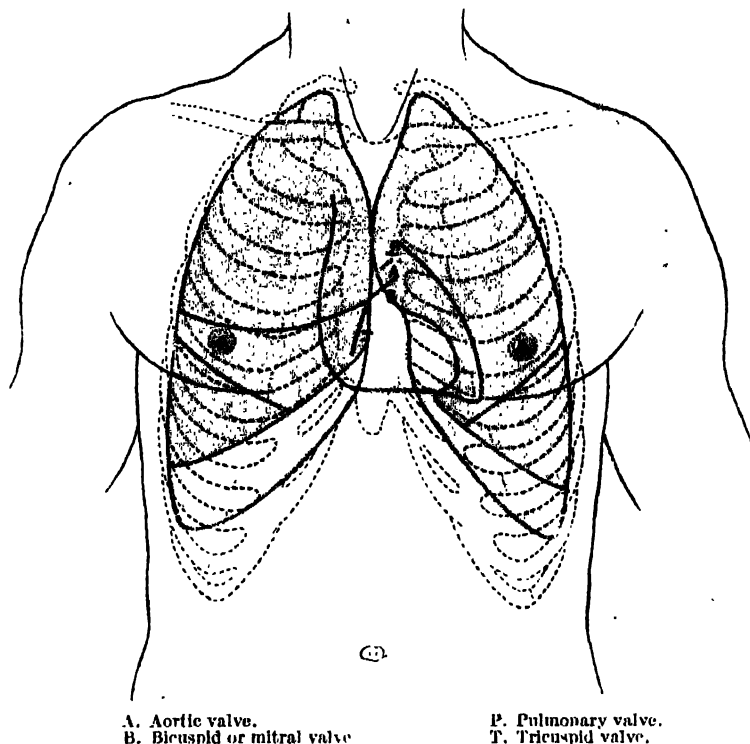
On either side of the thorax, from the axilla downwards, the external surfaces of the ribs may be defined. Although covered by muscles, all the ribs, with the exception of the first, can generally be followed without difficulty over the front

and sides of the thorax. The first rib, being almost completely covered by the clavicle, can only be distinguished in a small portion of its extent.

At the back, the angles of the ribs lie on slightly marked oblique lines some distance from the spinous processes of the vertebræ. The lines diverge somewhat as they descend, and laterally to each is a broad convex surface caused by the projection of the ribs beyond their angles. Over this surface, except where covered by the scapula, the individual ribs can be distinguished.

Muscles.—The surface muscles covering the thorax belong to the musculature of the upper extremity (figs. 1139, 1143), and will be described in that section

FIG. 1140.—Front of thorax, showing surface relations of bones, lungs (purple), pleuræ (blue), and heart (red outline).



(p. 1247). There is, however, an area of practical importance bounded by these muscles. It is limited above by the lower border of the Trapezius, below by the upper border of the Latissimus dorsi, and laterally by the vertebral border of the scapula; the floor is partly formed by the Rhomboideus major. If the scapulae be drawn forwards by folding the arms across the chest, and the trunk bent forwards, parts of the sixth and seventh ribs and the interspace between them become subcutaneous and available for auscultation. The space is therefore known as the *triangle of auscultation*.

Mamma.—The size of the mamma is subject to great variations. In the adult nulliparous female it extends vertically from the second to the sixth rib, and transversely from the side of the sternum to the midaxillary line. In the male and in the nulliparous female the *mammary papilla* or *nipple* is situated in the fourth interspace about 9 or 10 cm. from the middle line.

SURFACE MARKINGS OF THE THORAX

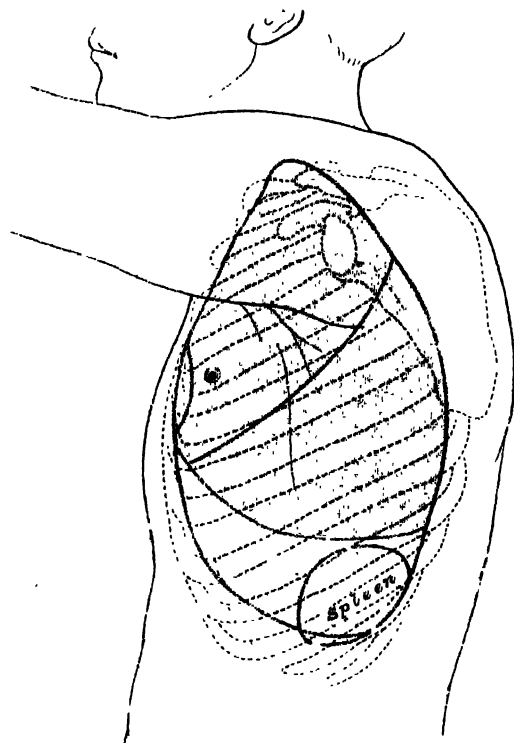
Bony landmarks.—The second costal cartilage corresponds to the sternal angle, and is so readily found that it is used as a starting-point from which to count the ribs. The lower border of the Pectoralis major at its origin corresponds to the

fifth rib; the uppermost visible digitation of the *Serratus anterior* indicates the sixth rib.

The jugular notch is at the level of the lower border of the body of the second thoracic vertebra, and the sternal angle at the level of the fibrocartilage between the fourth and fifth; the junction between the body and xiphoid process of the sternum corresponds to the fibrocartilage between the ninth and tenth thoracic vertebra.

The degree of obliquity of the ribs is such that 'if a horizontal line be drawn round the body at the level of the inferior angle of the scapula, while the arms

FIG. 1141.—Side of thorax, showing surface markings for bones, lung (purple), pleura (blue), and spleen (green).



are at the sides, the line would cut the sternum in front between the fourth and fifth ribs, the fifth rib in the nipple line and the ninth rib at the vertebral column.' (Treves.)

Diaphragm.—The shape and variations of the Diaphragm as seen by skiagraphy have already been described (p. 455)

Surface lines.—For clinical purposes, and for convenience of description, the surface of the thorax has been mapped out by arbitrary lines (fig. 1144). On the front of the thorax the most important vertical lines are the *midsternal* or middle line, and the *mammary* which descends vertically from a point midway between the centre of the jugular notch and the tip of the acromion, and, if prolonged, almost corresponds with the lateral line on the front of the abdomen. Other vertical lines are the *lateral sternal* along the sternal margin, and the *parasternal* midway between the latter and the mammary line (fig. 1144).

On either side of the thorax the *anterior* and *posterior axillary* lines are drawn vertically from the corresponding axillary folds; the *midaxillary* line runs downwards from the apex of the axilla.

On the posterior surface of the thorax the *scapular* line is drawn vertically through the inferior angle of the scapula.

Pleuræ (figs. 1140, 1141).—The lines of reflection of the pleuræ can be indicated on the surface. On the *right* side the line passes through the sternoclavicular

articulation and runs downwards and medialwards to the midpoint of the junction between the manubrium and body of the sternum. It follows the midsternal line to the lower end of the body of the sternum or on to the xiphoid process, and then turns lateralwards and downwards across the seventh sternocostal articulation. It crosses the eighth costochondral junction in the mammary line, the tenth rib in the midaxillary line, and is prolonged thence to the spinous process of the twelfth thoracic vertebra, to reach which it passes below the level of the medial part of the twelfth rib. The most dependent part of the pleural cavity is opposite the tenth rib in the midaxillary line.

On the *left* side the line passes through the sternoclavicular articulation, reaches the midpoint of the junction between the manubrium and body of the sternum, and extends down the midsternal line to the level of the fourth costal cartilage. It then inclines to the left and is continued downwards slightly laterally to the sternal border, as far as the sixth costal cartilage. Running downwards and lateralwards from this point it crosses the seventh costal cartilage, and from this onwards it is similar to the line on the right side but at a slightly lower level.

Lungs (figs. 1140, 1141).—The *apex* of the lung is situated in the neck above the medial third of the clavicle. The average height to which it rises above the clavicle is about 2.5 cm.

In order to mark out the *anterior borders* of the lungs two lines, one from each apex, are drawn downwards and medialwards across the sternoclavicular articulation and manubrium sterni until they meet, or almost meet, at the midpoint of the junction between the manubrium and body of the sternum. From this point the two lines run downwards, in the midsternal line, as far as the level of the fourth costal cartilages. On the *right* side the line is continued in the midsternal line to the level of the sixth costal cartilage, and then it turns lateralwards and downwards. On the *left* side the line curves lateralwards and downwards across the fourth sternocostal articulation to reach the parasternal line at the fifth costal cartilage, and then turns medialwards and downwards to the sixth sternocostal articulation.

In the position of expiration the *lower border* of the lung may be marked by a slightly curved line with its convexity downwards, from the sixth sternocostal junction to the tenth thoracic spinous process. This line crosses the mammary line at the sixth, the midaxillary line at the eighth, and the scapular line at the tenth rib.

The *posterior borders* of the lungs are indicated by lines drawn from the level of the spinous process of the seventh cervical vertebra, down either side of the vertebral column, across the costovertebral joints, as low as the spinous process of the tenth thoracic vertebra.

The position of the *oblique fissure* in either lung can be shown by a line drawn from the spinous process of the second thoracic vertebra round the side of the thorax to the sixth rib in the mammary line; this line corresponds roughly to that of the vertebral border of the scapula when the hand is placed on the top of the head. The *horizontal fissure* in the right lung is indicated by a line drawn from the midpoint of the preceding, or from the point where it cuts the midaxillary line, to the midsternal line at the level of the fourth costal cartilage.

The *roots* of the lungs are placed opposite to the spinous processes of the fourth, fifth and sixth thoracic vertebrae.

Trachea.—This may be marked out on the back by a line from the spinous process of the sixth cervical to that of the fourth thoracic vertebra, where it bifurcates; from its bifurcation the two bronchi are directed downwards and lateralwards. Anteriorly, the point of bifurcation is opposite to or a little below the sternal angle.

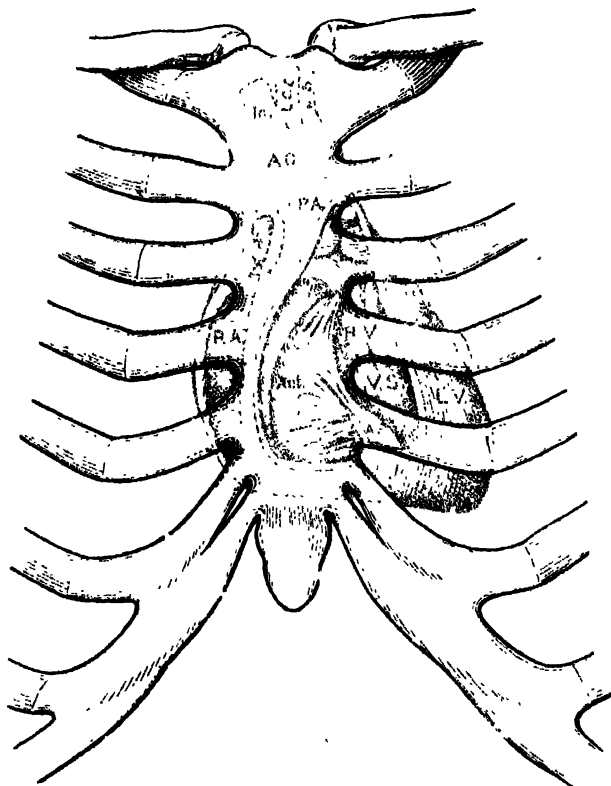
Œsophagus.—The extent of the œsophagus may be indicated on the back by a line from the sixth cervical spinous process to a point 2.5 cm. on the left of the ninth thoracic spinous process.

Heart.—The outline of the heart in relation to the front of the thorax (figs. 1140, 1142) can be represented by a quadrangular figure. (a) The apex of the heart is first determined as a point in the fifth interspace, 9 cm. to the left of the midsternal line. The other three points are: (b) the seventh right sternocostal articulation; (c) the upper border of the third right costal cartilage 1 cm. from the right lateral sternal line; (d) the lower border of the second left costal

cartilage 2.5 cm. from the left lateral sternal line. A line joining (a) to (b) and traversing the junction of the body of the sternum with the xiphoid process represents the lower border of the heart. The right and left borders are represented respectively by lines joining (c) and (a) to (c); both lines are convex lateralwards, but the convexity is more marked on the right, where its summit is 4 cm. distant from the midsternal line of the fourth costal cartilage.

A portion of the area of the heart thus mapped out is uncovered by lung, and therefore gives a dull note on percussion; the remainder is overlapped by lung and gives a more or less resonant note. The former is known as the area of superficial cardiac dullness, the latter as the area of deep cardiac dullness. The area

FIG. 1142.—Diagram showing relative position of heart to front of thoracic wall.



Ant. Anterior segment of tricuspid valve. A.O. Aorta. A.P. Anterior papillary muscle. In. Innominate artery. L.C.C. Left common carotid artery. L.S. Left subclavian artery. L.V. Left ventricle. P.A. Pulmonary artery. R.A. Right atrium. R.V. Right ventricle. V.S. Ventricular septum.

of superficial cardiac dullness is somewhat triangular; from the apex of the heart two lines are drawn to the midsternal line, one to the level of the fourth costal cartilage, the other to the junction between the body and xiphoid process of the sternum; the portion of the midsternal line between these points is the base of the triangle. Latham lays down the following rule as a sufficient practical guide for the definition of the area of superficial dullness: 'Make a circle of two inches in diameter round a point midway between the nipple and the end of the sternum.'

The *coronary sulcus* (auriculoventricular groove) can be indicated by a line from the third left, to the sixth right, sternocostal joint. The *anterior longitudinal sulcus* is a finger's-breadth to the right of the left margin of the heart and parallel with it.

The positions of the orifices of the heart are as follows: The *pulmonary orifice* is situated in the upper angle of the third left sternocostal articulation; the *aortic* is a little below and medial to this, close to the articulation. The *left atrioventricular* orifice is opposite the fourth costal cartilage, and rather to the left of the midsternal line; the *right atrioventricular* is a little lower, opposite the fourth interspace

of the right side. The lines indicating the atrioventricular orifices are parallel with and slightly below the line of the coronary sulcus.

Arteries.—The line of the *ascending aorta* begins slightly to the left of the mid-sternal line opposite the third costal cartilage, and extends upwards and to the right to the level of the upper border of the second right costal cartilage. The *aortic arch* lies behind the lower half of the manubrium sterni. A line from the middle of the manubrium sterni to the right sternoclavicular articulation represents the site of the *innominate artery*, while another line from a point slightly to the left of the middle of the manubrium sterni to the left sternoclavicular articulation indicates the position of the thoracic part of the *left common carotid artery*.

The *internal mammary artery* descends behind the first six costal cartilages about 1 cm. from the lateral sternal line.

Veins.—The line of the *right innominate vein* crosses the right sternoclavicular joint and the upper border of the first right costal cartilage about 1 cm. from the lateral sternal line; that of the *left innominate vein* extends from the left sternoclavicular articulation to meet the right at the upper border of the first right costal cartilage. The junction of the two lines indicates the origin of the *superior vena cava*, and the line of this vessel is continued vertically down to the level of the third right costal cartilage. The *inferior vena cava* opens into the right atrium at the level of the upper margin of the sixth right costal cartilage about 2 cm. from the midsternal line.

SURFACE ANATOMY OF THE ABDOMEN

Skin.—The skin of the front of the abdomen is thin. In the male it is often thickly clad with hairs, especially towards the lower part of the middle line; in the female the hairs are confined to the pubes. Just below the iliac crest is a shallow groove termed the *iliac furrow*, while in the site of the inguinal ligament a sharper fold known as the *fold of the groin* is easily distinguishable.

After distension of the abdomen from pregnancy or other causes the skin commonly presents transverse white lines which are quite smooth, being destitute of papillae; these are known as *striae gravidarum* or *striae albae*. The *linea nigra* of pregnancy is often seen as a brown streak in the middle line between the umbilicus and symphysis pubis.

In the middle line of the front of the abdomen is a shallow furrow which extends from the junction between the body of the sternum and the xiphoid process to a short distance below the umbilicus; it corresponds to the *linea alba*. The umbilicus is situated in the middle line, but varies as regards its height; in an adult subject it is always placed above the middle point of the body, and is slightly below the level of the highest points of the iliac crests.

Bones.—The bones in relation with the surface of the abdomen are (1) the lower part of the vertebral column and the lower ribs and (2) the pelvis; the former have already been described (pp. 1226 and 1229), the latter will be considered with the lower limb.

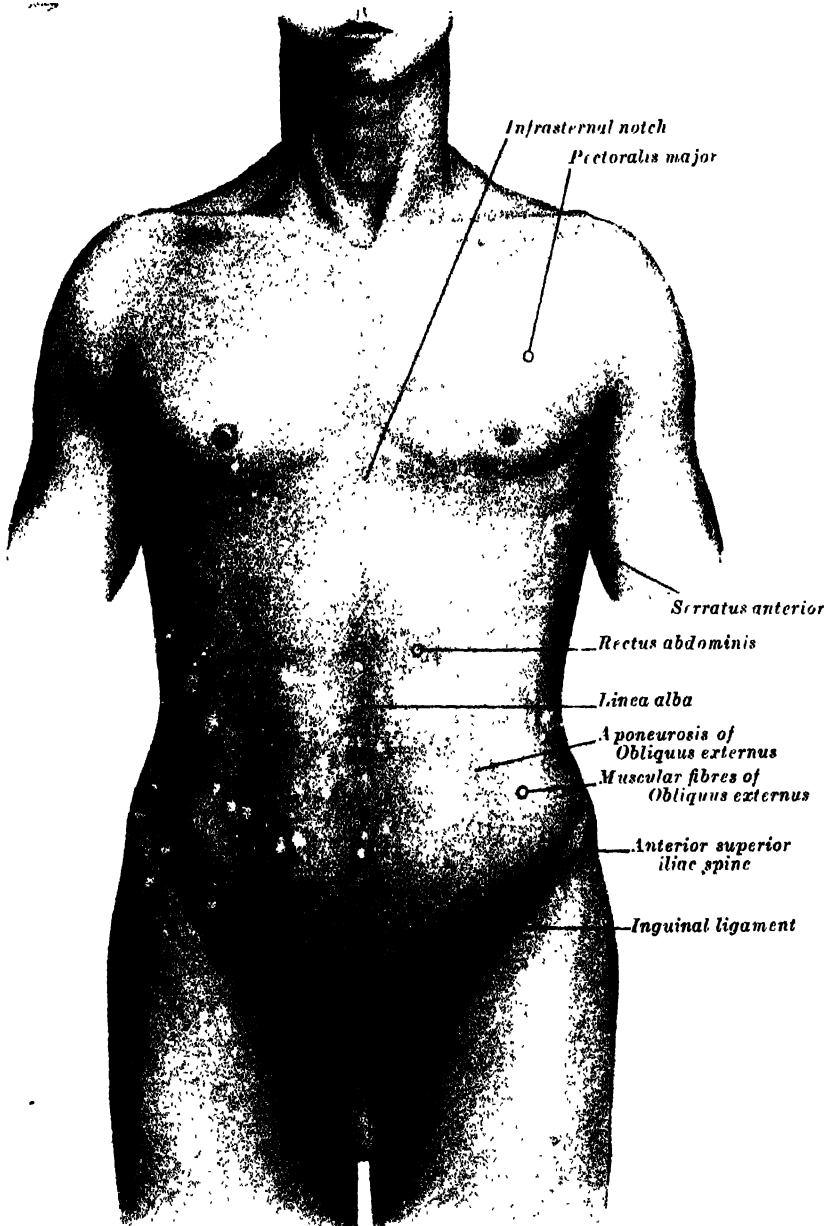
Muscles (fig. 1143).—The only muscles of the abdomen which have any considerable influence on surface form are the *Obliquus externus abdominis* and the *Rectus abdominis*. The upper digitations of origin of the *Obliquus externus* are well marked and interdigitate with those of the *Serratus anterior*; the lower are covered by the border of the *Latissimus dorsi*. The attachment of the *Obliquus externus* and *Obliquus internus* to the iliac crest forms a thick oblique roll which terminates the iliac furrow. On the front of the lateral region of the abdomen an undulating line sometimes marks the passing of the muscular fibres of the *Obliquus externus* into its aponeurosis. The posterior margin of the *Obliquus externus* is frequently separated from the lateral margin of the *Latissimus dorsi* by a small angular interval—the *lumbar triangle*—the base of which is formed by the iliac crest, and the floor by the *Obliquus internus*.

The lateral margin of the *Rectus abdominis* is indicated by the *linea semilunaris*, which is easily defined when the muscle is in action. On the surface of the *Rectus* three transverse furrows, the *tendinous inscriptions*: the upper two of these, one opposite, or a little below, the tip of the xiphoid process, and the other midway between this point and the umbilicus, are usually well marked; the third, opposite the umbilicus, is not so distinct. Between the two *Recti* the furrow of

the linea alba can be traced from the xiphoid process to a point just below the umbilicus, beyond which it disappears owing to the apposition of the muscles.

Vessels.—In thin subjects the pulsation of the *abdominal aorta* is felt on making deep pressure in the middle line above the umbilicus.

FIG. 1143.—Surface anatomy of the front of the thorax and abdomen.



Viscera.—Under normal conditions the various portions of the *digestive tube* cannot be identified by simple palpation, but under certain conditions peristalsis of the coils of small intestine can be observed in persons with extremely thin abdominal walls. In cases of constipation it is commonly possible to trace portions of the great intestine by feeling the faecal masses within the gut. In thin persons with relaxed abdominal walls the iliac portion of the descending colon can be felt

in the left iliac region—rolling under the fingers when empty and forming a distinct tumour when distended.

The *liver* lies mainly under cover of the lower ribs and their cartilages, but in the epigastric fossa a portion of it comes in contact with the abdominal wall. The position of the liver varies according to the posture of the body. In the erect posture the inferior margin of the liver projects about 1 cm. below the lower margin of the right costal cartilages, and can often be felt if the abdominal wall is thin. In the supine position the liver recedes above the lower margin of the thorax and cannot then be detected by the fingers; in the prone position it falls forwards and is then generally palpable in a patient with lax abdominal walls. Its position varies with the respiratory movements: during a deep inspiration it descends below the ribs, in expiration it is raised. Pressure from without, as in tight lacing, displaces the liver considerably, its anterior edge frequently extending as low as the iliac crest. Again, the position of the liver varies greatly with the state of the stomach and intestines; when these are empty the liver descends, when they are distended it is pushed upwards.

The *pancreas* can sometimes be felt in emaciated subjects, if the stomach and colon are empty, by making deep pressure in the middle line about 7 or 8 cm. above the umbilicus.

The *kidneys* are deeply situated at the back of the abdominal cavity, and cannot be palpated unless enlarged or misplaced.

SURFACE MARKINGS OF THE ABDOMEN

Bony landmarks.—Above, the chief bony markings are the xiphoid process, the lower six costal cartilages and the anterior ends of the lower six ribs. The junction between the body of the sternum and the xiphoid process is at the level of the tenth thoracic vertebra. Below, the main landmarks are the symphysis pubis and the pubic crest and tubercle, the anterior superior iliac spine, and the iliac crest.

Muscles (fig. 1143).—The *Rectus abdominis* lies between the linea alba and the linea semilunaris; the latter is indicated by a curved line, convex lateralwards, from the tip of the cartilage of the ninth rib to the pubic tubercle; at the level of the umbilicus the linea semilunaris is about 7 cm. from the middle line. The line indicating the junction of the muscular fibres of *Obliquus externus* with its aponeurosis extends from the tip of the ninth costal cartilage to a point just medially to the anterior superior iliac spine.

The *umbilicus* is at the level of the fibrocartilage between the third and fourth lumbar vertebrae.

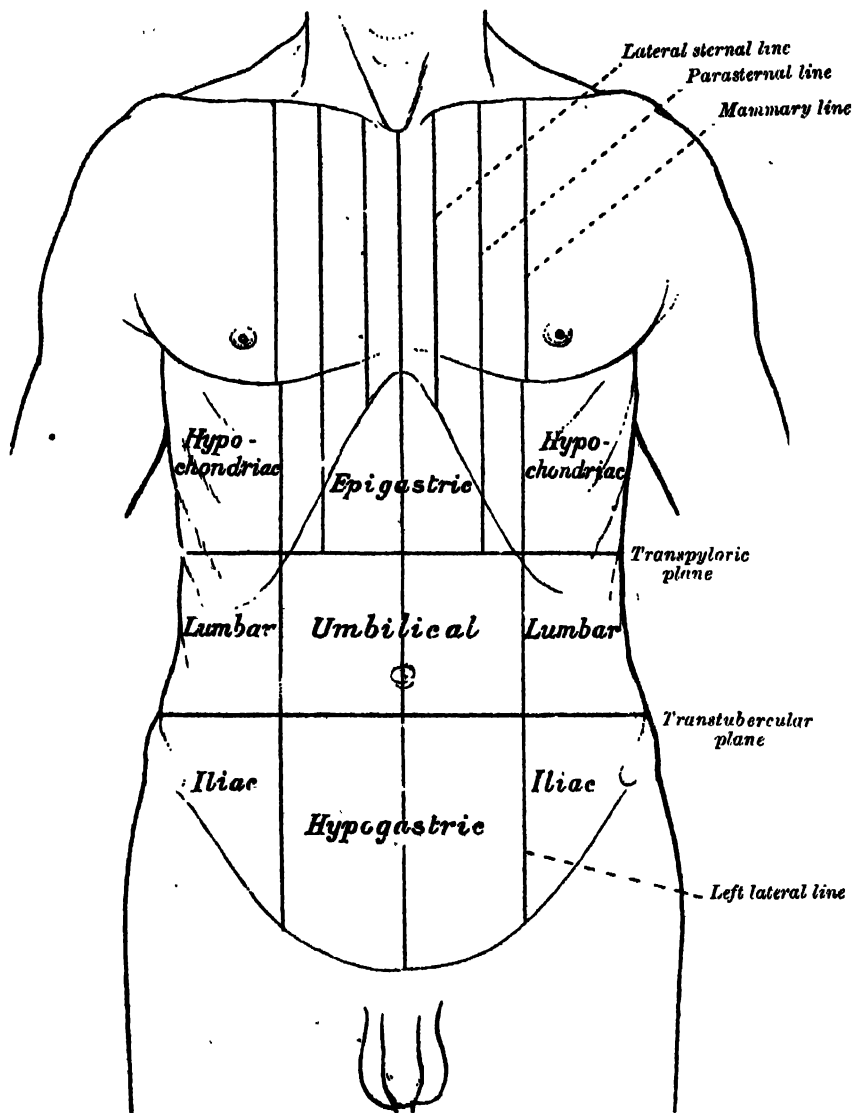
The *subcutaneous inguinal ring* is situated 1 cm. above and lateral to the pubic tubercle; the *abdominal inguinal ring* is about 1 cm. above the middle of the inguinal ligament. The position of the *inguinal canal* is indicated by a line joining these two points.

Surface lines.—For convenience of description of the viscera and of reference to morbid conditions of the contained parts, the abdomen is divided into nine regions, by imaginary planes, two horizontal and two sagittal, the edges of the planes being indicated by lines drawn on the surface of the body (fig. 1144). In the older method the upper, or subcostal, horizontal line encircles the body at the level of the lowest points of the tenth costal cartilages; the lower, or inter-tubercular, is a line carried through the highest points of the iliac crests seen from the front, i.e. through the tubercles on the iliac crests about 5 cm. behind the anterior superior spines. An alternative method is that of Addison, who adopts the following lines: (1) an upper transverse, the *transpyloric*, halfway between the jugular notch and the upper border of the symphysis pubis; this indicates the edge of the transpyloric plane which in most cases cuts through the pylorus, the tips of the ninth costal cartilages and the lower border of the first lumbar vertebra; (2) a lower transverse line midway between the transpyloric and the upper border of the symphysis pubis; this is termed the *trans-tubercular* since it very nearly corresponds to that passing through the tubercles on the iliac crests; behind, its plane cuts the body of the fifth lumbar vertebra.

By means of these horizontal planes the abdomen is divided into three zones named from above, subcostal, umbilical, and hypogastric. Each of these is further

subdivided into three regions by the two sagittal planes, which are indicated on the surface by a right and a left lateral line drawn vertically through points halfway between the anterior superior iliac spine and the middle line. The middle region of the upper zone is called the epigastric, and the lateral regions the right and left hypochondriac. The central region of the middle zone is the umbilical, and the lateral regions the right and left lumbar. The middle region

FIG. 1144.—Surface lines of the front of the thorax and abdomen.



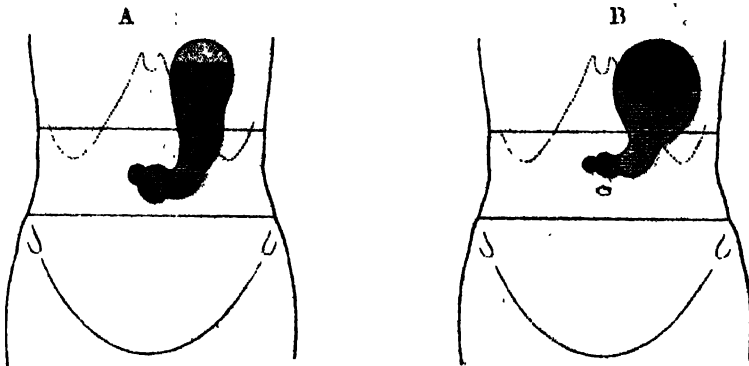
of the lower zone is the hypogastric or pubic, and the lateral regions are the right and left iliac or inguinal. The epigastric, umbilical, and pubic regions can each be divided into right and left portions by the middle line. In the following description of the viscera the regions marked out by Addison's lines are those referred to.

Stomach (fig. 1146).—The shape of the stomach is constantly undergoing alteration; it is affected by the particular phase of the process of gastric digestion, by the state of the surrounding viscera, and by the amount and character of its contents. Its position also varies with that of the body (fig. 1145), so that it is impossible to indicate it on the surface with any degree of accuracy. The measurements given refer to a moderately filled stomach with the body in the supine position.

The cardiac orifice is opposite the seventh left costal cartilage, about 2.5 cm. from the side of the sternum; it corresponds to the level of the tenth thoracic vertebra. The pyloric orifice is on the transpyloric line about 1 cm. to the right of the middle line, or alternatively 5 cm. below the seventh right sternocostal articulation; it is at the level of the first lumbar vertebra. A curved line, convex downwards and to the left, joining these points indicates the lesser curvature. In the left lateral line the fundus of the stomach reaches as high as the fifth intercostal space or the sixth costal cartilage, a little below the apex of the heart. To indicate the greater curvature a curved line is drawn from the cardiac orifice to the summit of the fundus, thence downwards and to the left, finally turning medialwards to the pyloric orifice, but passing, on its way, through the intersection of the left lateral with the transpyloric line. The portion of the stomach which is in contact with the abdominal wall can be represented roughly by a triangular area, the base of which is formed by a line drawn from the tip of the tenth left costal cartilage to the tip of the ninth right cartilage, and the sides by two lines drawn from the end of the eighth left costal cartilage to the ends of the base line.

A space of some clinical importance—the *space of Traube*—overlies the stomach and may be thus indicated. It is semilunar in outline and has the following

FIG. 1145.—Skiagrams of a moderately distended stomach, showing the influence of posture. (Modified from Hertz.)



A. With the patient in the erect posture. B. With the patient lying down.

boundaries: the lower edge of the left lung, the anterior border of the spleen, the left costal margin, and the inferior margin of the left lobe of the liver.

Duodenum (fig. 1147).—The superior part is nearly horizontal and extends from the pylorus to the right lateral line; the descending part is situated medially to the right lateral line, from the transpyloric line to a point midway between the transpyloric and transtuberular lines. The horizontal part runs with a slight upward slope from the end of the descending part to the left of the middle line; the ascending part is vertical, and ends in the duodenojejunal flexure, about 2.5 cm. to the left of the middle line and a little below the transpyloric plane.

Small intestine.—The coils of small intestine occupy the front of the abdomen. For the most part those of the jejunum are situated on the left side, i.e. in the left lumbar and iliac regions, and in the left half of the umbilical region. Those of the ileum lie towards the right in the right lumbar and iliac regions, in the right half of the umbilical region, and in the hypogastric region; a portion of the ileum is within the pelvis. The end of the ileum, i.e. the *ileocolic junction*, is slightly below and medial to the intersection of the right lateral and transtuberular lines.

Cæcum and vermiform process.—The cæcum is in the right iliac and hypogastric regions; its position varies with its degree of distension, but the midpoint of a line drawn from the right anterior superior iliac spine, to the upper margin of the symphysis pubis will mark approximately the middle of its lower border.

The position of the opening of the *vermiform process* into the cæcum is indicated by a point on the lateral line on a level with the anterior superior iliac spine.

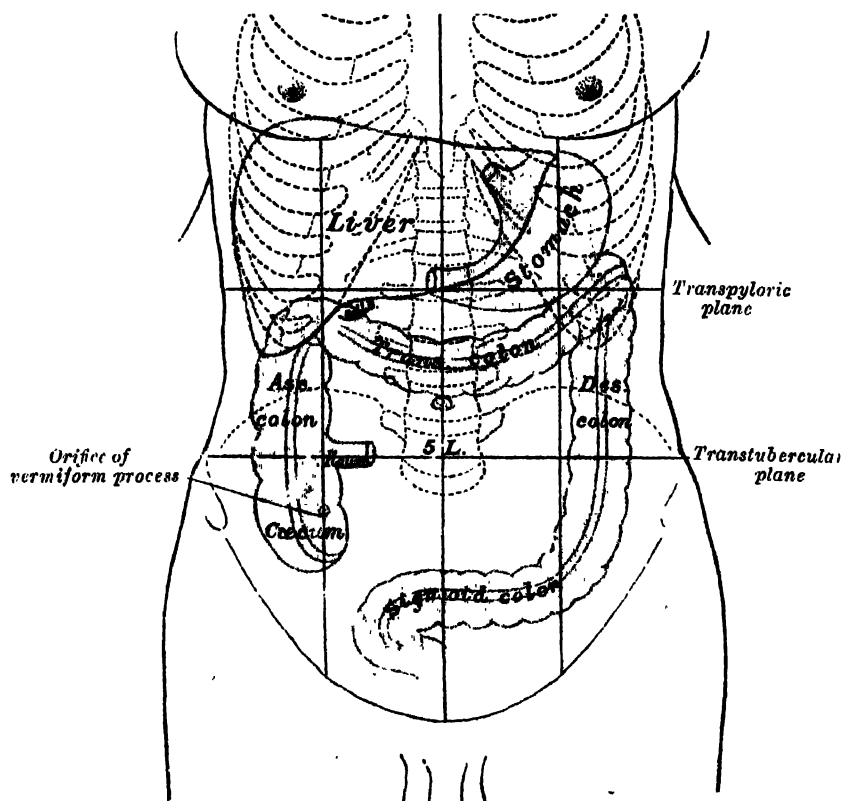
Ascending colon.—The ascending colon passes upwards through the right lumbar region, just laterally to the right lateral line. The *right colic flexure* is situated in the right lower angle of intersection of the transpyloric and right lateral lines.

Transverse colon.—The transverse colon crosses the abdomen on the confines of the umbilical and epigastric regions, its lower border being on a level slightly above the umbilicus, its upper border just below the greater curvature of the stomach.

Descending colon.—The *left colic flexure* is situated in the upper left angle of the intersection between the left lateral and transpyloric lines. The descending colon courses down through the left lumbar region, laterally to the left lateral line, thence slightly medialwards to the left lateral line at the level of the anterior superior iliac spine.

Liver (fig. 1146).—The upper limit of the right lobe of the liver, in the middle line, is at the level of the junction between the body and xiphoid process of the

FIG. 1146.—Front of abdomen, showing surface markings for liver, stomach, and great intestine.

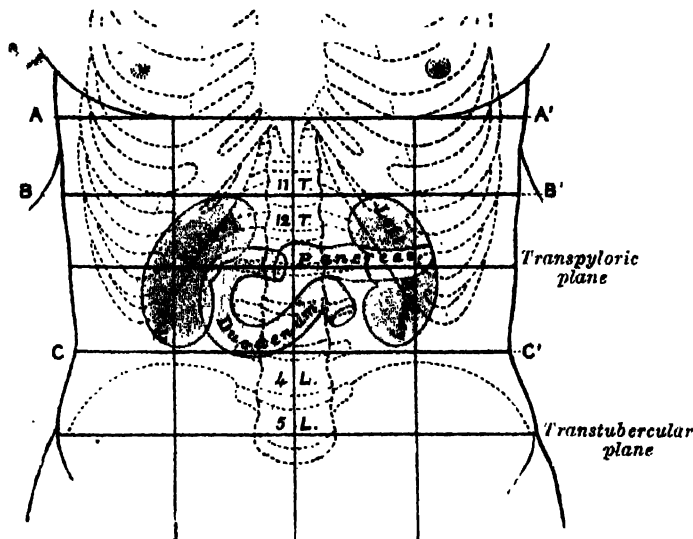


sternum ; on the right side the line must be carried upwards as far as the fifth costal cartilage in the mammary line, and then downwards to reach the seventh rib at the side of the thorax. The upper limit of the left lobe can be defined by continuing this line to the sixth left costal cartilage, 5 cm. from the middle line. The lower limit is represented by a line drawn 1 cm. below the lower margin of the thorax on the right side as far as the ninth costal cartilage, thence obliquely upwards to the eighth left costal cartilage, crossing the middle line at the transpyloric plane and finally, with a slight left convexity, to the end of the line indicating the upper limit.

According to Birmingham, the limits of the normal liver may be marked out on the surface of the body in the following manner. Take three points : (a) 1.25 cm. below the right nipple ; (b) 1.25 cm. below the tip of the right tenth rib ; (c) 2.5 cm. below the left nipple. Join (a) and (c) by a line slightly concave upwards at its middle part ; (a) and (b) by a line slightly convex lateralwards ; and (b) and (c) by a line slightly convex downwards.

The fundus of the *gall-bladder* approaches the surface behind the anterior end of the ninth right costal cartilage close to the lateral margin of the *Rectus abdominis*.

FIG. 1147.—Front of abdomen, showing surface markings for duodenum, pancreas and kidneys.



A A'. Plane through joint between body and xiphoid process of sternum. B B'. Plane midway between A A' and transpyloric plane. C C'. Plane midway between transpyloric and transtubercular planes.

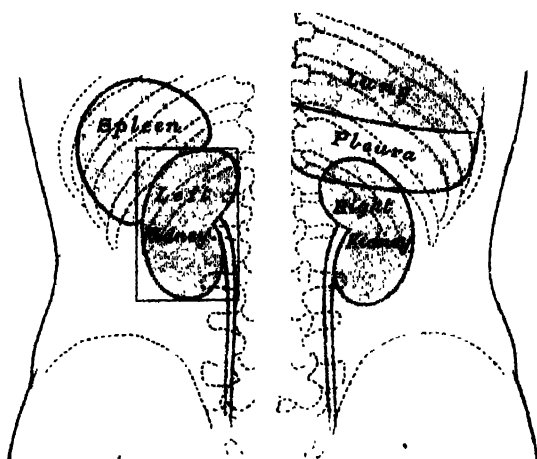
Pancreas (fig. 1147).—The pancreas lies in front of the second lumbar vertebra. Its head occupies the curve of the duodenum, and is therefore indicated by the same lines as that viscus; its neck corresponds to the pylorus. Its body extends along the transpyloric line, the bulk of it lying above this line, to the tail, which is in the left hypochondriac region slightly to the left of the lateral line and above the transpyloric line.

Spleen (figs. 1141, 1148).—To map out the spleen the tenth rib is taken as representing its long axis; vertically it extends from the upper border of the ninth rib to the lower border of the eleventh rib. The highest point is 4 cm. from the middle line of the back at the level of the tip of the ninth thoracic spinous process; the lowest and foremost point is in the midaxillary line at the level of the first lumbar spinous process.

Kidneys (figs. 1147, 1148).—The right kidney usually lies about 1 cm. lower than the left, but for practical purposes similar surface markings are taken for each.

On the front of the abdomen the upper pole lies midway between the plane of the lower end of the body of the sternum and the transpyloric plane, 5 cm. from

FIG. 1148.—Back of lumbar region, showing surface markings for kidneys, ureters, and spleen.

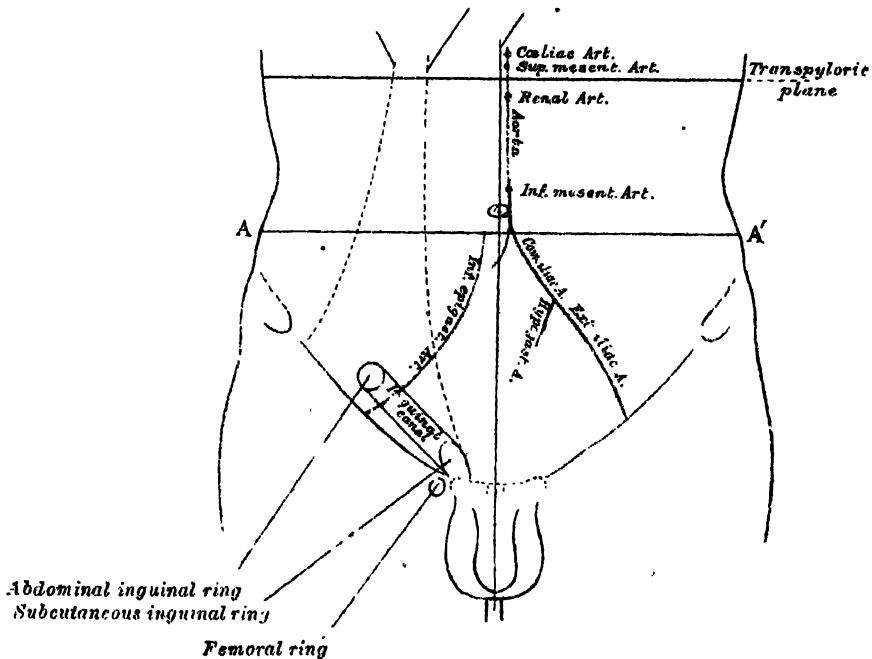


The lower portions of the lung and pleura are shown on the right side.

the middle line. The lower pole is situated midway between the transpyloric and transtuberular planes, 7 cm. from the middle line. The hilum is on the transpyloric plane, 5 cm. from the middle line.* Round these three points a kidney-shaped figure 4 cm. to 5 cm. broad is drawn two-thirds of which lie medially to the lateral line. To indicate the position of the kidney from the back, the parallelogram of Morris is used; two vertical lines are drawn, the first 2.5 cm., the second 9.5 cm. from the middle line; the parallelogram is completed by two horizontal lines, one drawn at the level of the tip of the spinous process of the eleventh thoracic vertebra, and the other at the level of the lower border of the spinous process of the third lumbar vertebra. The hilum is 5 cm. from the middle line at the level of the spinous process of the first lumbar vertebra.

Ureters.—On the front of the abdomen, the line of the ureter is from the hilum of the kidney to the pubic tubercle; on the back, from the hilum vertically downwards, passing through the posterior superior iliac spine (fig. 1148).

FIG. 1149.—Front of abdomen, showing surface markings for arteries and inguinal canal. The line A, A' is drawn at the level of the highest points of the iliac crests.



Vessels (fig. 1149).—The position of the *inferior epigastric artery* is marked by a line from a point midway between the anterior superior iliac spine and the pubic symphysis to the umbilicus. This line also indicates the lateral boundary of *Hesselbach's triangle*, the other boundaries of which are the lateral edge of *Rectus abdominis*, and the medial half of the inguinal ligament. The line of the *abdominal aorta* begins in the middle line about 4 cm. above the transpyloric line and ends at a point 2 cm. below and to the left of the umbilicus—or 2 cm. to the left of the middle line at the level of the highest points of the iliac crests (AA', fig. 1149); the abdominal aorta ends at the level of the fourth lumbar vertebra. A line drawn from the point of termination of the abdominal aorta to a point midway between the anterior superior iliac spine and the symphysis pubis overlies the common and external iliac arteries. The *common iliac* is represented by the upper one-third, and the *external iliac* by the lower two-thirds of this line.

Of the larger branches of the abdominal aorta, the *celiac artery* is 4 cm., and the *superior mesenteric* 2 cm. above the transpyloric line; the *renal arteries* are 2 cm.

* Addison says (1) that one-third of the right kidney and two-fifths of the left are above the transpyloric plane, and (2) that one-third of the right kidney and two-fifths of the left lie on the medial side of the corresponding lateral line.

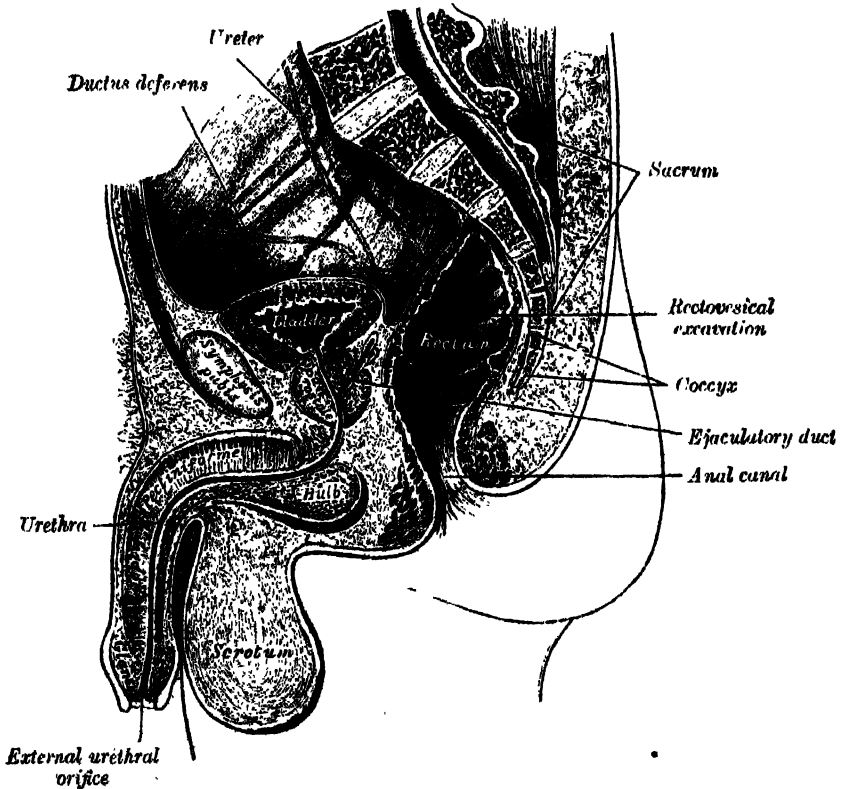
below this line. The *inferior mesenteric artery* is 4 cm. above the bifurcation of the abdominal aorta.

Nerves.—The courses of the lower six thoracic nerves on the anterior abdominal wall are represented by lines continuing those of the ribs. The seventh thoracic nerve ends at the level of the xiphoid process, the tenth at the level of the umbilicus, and the twelfth about midway between the umbilicus and the upper border of the symphysis pubis. The anterior branch of the iliohypogastric nerve becomes cutaneous about 3 cm. above the subcutaneous inguinal ring; the ilio-inguinal nerve at the ring.

SURFACE ANATOMY OF THE PERINÆUM

• **Skin.**—In the middle line of the posterior part of the perinæum and about 4 cm. in front of the tip of the coccyx is the anal orifice, the skin around which is thrown into a series of folds which converge towards the orifice, and are continued

FIG. 1150.—Median sagittal section of male pelvis.



upwards into the lower part of the anal canal. The junction of the mucous membrane of the anal canal with the skin is marked by a white line which indicates also the line of contact of the external and internal Sphincters. The external genital organs are situated in the anterior part of the perinæum. The skin covering the scrotum is rough and corrugated, but over the penis it is smooth. Extending forwards from the anus on to the scrotum and penis is a median ridge which indicates the scrotal raphe. In the *female* are seen the skin reduplications forming the labia majora and minora laterally, the prepuce of the clitoris in front, and still more anteriorly the mons pubis (fig. 1151).

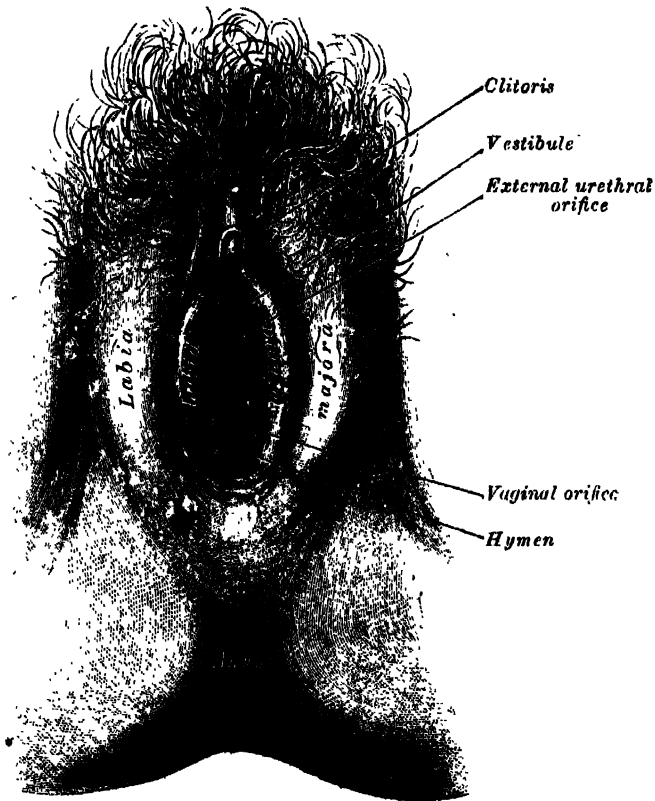
Bones.—In the anterolateral boundaries of the perinæum, the whole outline of the pubic arch can be readily traced ending in the ischial tuberosities. Behind in the middle line is the tip of the coccyx.

Muscles and ligaments.—The margin of the *Gluteus maximus* forms the posterolateral boundary of the perineum, and by pressing deeply the sacrotuberous ligament can be felt through the muscle. The only other muscles influencing surface form are the *Ischiocavernosus* covering the crus penis, which lies on the side of the pubic arch, and the *Sphincter ani externus*, which, in action, closes the anal orifice and causes a puckering of the skin around it.

SURFACE MARKINGS OF THE PERINEUM

A line drawn transversely in front of the ischial tuberosities divides the perineum into a posterior or rectal, and an anterior or urogenital, triangle. This line passes through the central point of the perineum, which is situated about 2.5 cm. in front of the anal aperture, or, in the male, midway between the anus and the reflection of the skin on to the scrotum.

FIG. 1151.—External genital organs of female. The labia minora have been drawn apart.

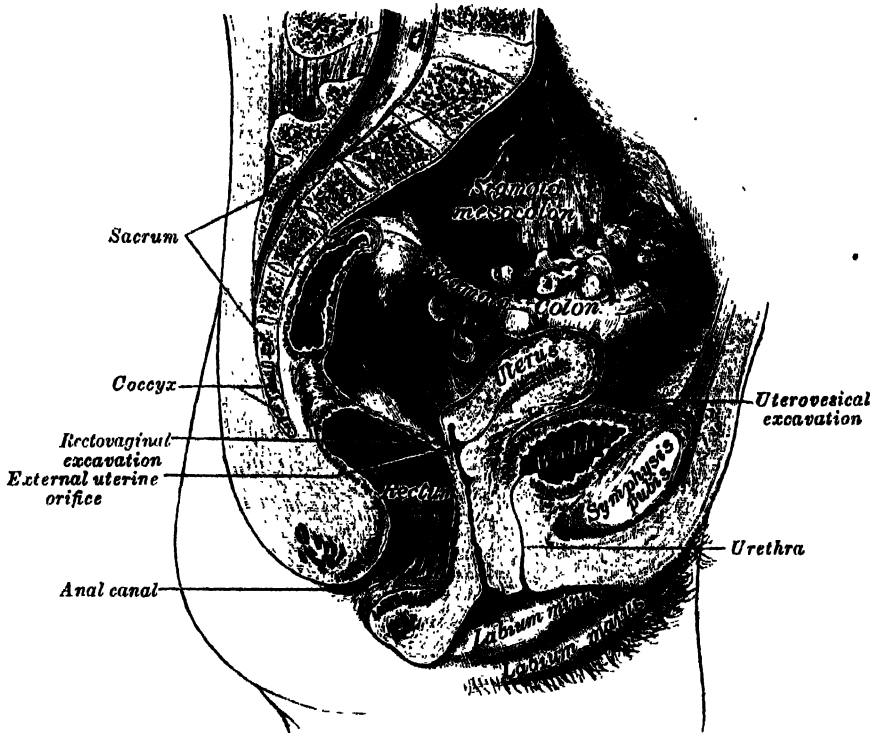


Rectum and Anal canal.—A finger inserted through the anal orifice is grasped by the *Sphincter ani externus*, passes into the region of the *Sphincter ani internus*, and higher up encounters the resistance of the *Puborectalis*; beyond this it may reach the lowest of the transverse rectal folds. In front (fig. 1150), the urethral bulb and membranous part of the urethra are first identified, and then about 4 cm. above the anal orifice the prostate is felt; beyond this the *vesiculæ seminales*, if enlarged, and the fundus of the bladder, when distended, can be recognised. On either side is the ischio-rectal fossa. Behind are the *anococcygeal body*, the pelvic surfaces of the coccyx and lower part of the sacrum, and the *sacrospinous ligaments*.

In the female the posterior wall and fornix of the vagina, and the cervix and body of the uterus can be felt in front, while somewhat laterally the ovaries can just be reached.

Male urogenital organs.—The corpora cavernosa penis can be followed backwards to the crura which are attached to the sides of the pubic arch. The glans penis, covered by the prepuce, and the external urethral orifice can be examined, and the course of the urethra traced along the under surface of the penis to the urethral bulb which is situated immediately in front of the central point of the perinæum. The testes can be palpated through the wall of the scrotum, and along the posterior border of each the curved epididymis can be felt; the spermatic cord ascends on the medial side of the epididymis, and may be traced upwards to the subcutaneous inguinal ring. The ductus deferens feels like a piece of whipcord, and thus can be easily recognized in the posterior part of the spermatic cord.

FIG. 1152.—Median sagittal section of female pelvis.



By means of a sound the general topography of the urethra and bladder can be investigated; with the urethroscope the interior of the urethra can be illuminated and viewed directly; with the cystoscope the interior of the bladder is in a similar manner illuminated for visual examination. In the bladder the main points to which attention is directed are: the trigone, the torus uretericus, the plicæ uretericæ, and the openings of the ureters and urethra (see fig. 1075).

Female urogenital organs.—In the pudendal cleft (fig. 1151) between the labia minora are the openings of the vagina and urethra. In the virgin the vaginal opening is partly closed by the hymen—after coitus the remains of the hymen are represented by the caruncula hymenales. Between the vaginal orifice and the frenulum of the labia is the fossa navicularis, while in the groove between the hymen and the labium minus, on either side, the small opening of the greater vestibular (Bartholin's) gland is visible. These glands when enlarged can be felt on either side of the posterior part of the vaginal orifice. By inserting a finger into the vagina the following structures may be examined through its wall (fig. 1152). Behind, from below upwards, are the anal canal, the rectum, and the recto-uterine

excavation. Projecting into the roof of the vagina is the vaginal portion of the cervix uteri with the external uterine orifice; in front of and behind the cervix are the anterior and posterior vaginal fornices. With a finger in the vagina and the other hand on the abdominal wall the whole of the cervix and body of the uterus, the uterine tubes, and the ovaries can be palpated. If a speculum be introduced into the vagina, the walls of the passage, the vaginal portion of the cervix, and the external uterine orifice can all be exposed for visual examination.

The external urethral orifice lies in front of the vaginal opening, and has rather prominent margins. The urethral canal in the female is very dilatable and can be explored with the finger. About 2.5 cm. in front of the external orifice of the urethra are the glans and prepuce of the clitoris, and still further forward, the mons pubis.

SURFACE ANATOMY OF THE UPPER EXTREMITY

Skin.—The skin covering the shoulder and arm is smooth and very movable on the underlying structures. In the axilla there are numerous hairs and many sudoriferous and sebaceous glands. On the medial side and front of the forearm the skin is thin and smooth, and contains few hairs but many sudoriferous glands; on the lateral side and back of the arm and forearm it is thicker, denser, and contains more hairs but fewer sudoriferous glands. In the region of the olecranon it is thick and rough; it is very loosely connected to the underlying tissue, and falls into transverse wrinkles when the forearm is extended. At the front of the wrist there are three transverse furrows in the skin; they correspond respectively from above downwards to the positions of the styloid process of the ulna, the radiocarpal or wrist-joint, and the midcarpal joint.

The skin of the palm of the hand is hard and dense and covered with a thick layer of epidermis; on the thenar eminence these characteristics are less marked than elsewhere. It is exceedingly sensitive and very vascular, but is destitute of hairs and sebaceous glands. It is tied down by fibrous bands along the lines of flexion of the digits, and exhibits certain furrows of a permanent character. One of these furrows begins in front of the wrist at the tuberosity of the navicular bone, curves round the thenar eminence, and ends on the lateral border of the hand near the level of the metacarpophalangeal joint of the index finger; a second begins at the distal end of the first and extends obliquely across the palm to reach the medial border about the middle of the fifth metacarpal bone; a third begins at the medial border about 2.5 cm. distally to the end of the second, and extends across the heads of the fifth, fourth, and third metacarpal bones. The medial part of the third line and the lateral part of the second line lie in front of the metacarpophalangeal joints of the fingers. The proximal segments of the fingers are joined to one another on the volar aspect by folds of skin constituting the 'web' of the fingers; these folds are about opposite the level of the centres of the proximal phalanges and their free margins are continuous with the transverse furrows at the roots of the fingers. Since the web is confined to the volar aspect, the fingers appear shorter when viewed from in front than from behind. Over the fingers and thumb the skin is thinner, especially at the flexures of the joints (where it is crossed by transverse furrows) and over the terminal phalanges; it is disposed in numerous ridges in consequence of the arrangement of the papillae in it. These ridges form, in different individuals, distinctive and permanent patterns which can be used for purposes of identification.

The superficial fascia in the palm of the hand is made up of dense fibrofatty tissue which binds the skin so firmly to the palmar aponeurosis that very little movement is permitted between the two.

On the back of the hand and fingers the subcutaneous tissue is lax, and the skin is freely movable on the underlying parts. Over the interphalangeal joints it is very loose and is thrown into transverse wrinkles when the fingers are extended.

Bones.—The clavicle can be felt throughout its entire length. The enlarged sternal end projects above the sternum at the side of the jugular notch, and from this the body of the bone can be traced laterally under the skin. The medial part is convex forwards, but the surface is partially obscured by the attachments of the Sternocleidomastoides and Pectoralis major; the lateral end is convex

forwards and ends in a slight enlargement at the acromion of the scapula. The clavicle is almost horizontal when the arm is lying by the side, although in muscular subjects it may incline a little upwards at its acromial end, which is on a plane posterior to the sternal end.

The only parts of the *scapula* that are subcutaneous are the spine and acromion, but the coracoid process, the vertebral border, the inferior angle, and to a lesser extent the axillary border can be readily defined. The acromion and spine are easily recognisable throughout their entire extent, forming with the clavicle the arch of the shoulder. The acromion forms the point of the shoulder; it joins the clavicle at an acute angle—the acromial angle—slightly medially to, and behind the tip of the acromion. The spine can be felt in the floor of an oblique depression and becomes less distinct when traced medialwards; it ends in a slight dimple a little laterally to the spinous process of the third thoracic vertebra. Below this point the vertebral border may be followed downwards and lateralwards to the inferior angle, which is easily identified although covered by the *Latissimus dorsi*. From the inferior angle the axillary border may be traced upwards through its thick muscular covering, forming with its enveloping muscles the posterior fold of the axilla; this fold is more vertical in direction than the anterior fold of the axilla, and can be seen from the front. The coracoid process is situated about 2 cm. below the junction of the intermediate with the lateral third of the clavicle; it is covered by the anterior border of the *Deltoides*, and thus lies a little laterally to the infraclavicular fossa or depression which marks the interval between the *Pectoralis major* and *Deltoides*.

The *humerus* is almost entirely surrounded by muscles, and the only parts which are subcutaneous are its medial and lateral epicondyles; in addition to these, however, the tubercles and a part of the head of the bone can be felt under the skin and muscles by which they are covered. The greater tubercle forms the most prominent bony point of the shoulder, extending beyond the acromion; it is best recognised when the arm is lying passive by the side, for if the arm be raised it recedes under the arch of the shoulder. The lesser tubercle, directed forwards, is medial to the greater and separated from it by the intertubercular sulcus, which can be made out by deep pressure. When the arm is abducted the lower part of the head of the humerus can be felt by pressing deeply in the axilla. On either side of the elbow-joint and just above it are the medial and lateral epicondyles. Of these, the former is the more prominent, but the medial supracondylar ridge is much less marked than the lateral, and as a rule is not palpable; occasionally, however, the hook-shaped supracondylar process (p. 277) is found on this border. The position of the lateral epicondyle is best seen during semiflexion of the forearm, and is indicated by a depression; from it the strongly marked lateral supracondylar ridge runs upwards.

The most prominent part of the *ulna*, the olecranon, can always be identified at the back of the elbow-joint; when the forearm is flexed its upper quadrilateral surface is palpable, but during extension it recedes into the olecranon fossa. During extension the upper border of the olecranon is slightly above the level of the medial epicondyle and nearer to this than to the lateral; when the forearm is fully flexed the olecranon and the epicondyles form the angles of an equilateral triangle. On the back of the olecranon is a smooth triangular subcutaneous surface, and running down the back of the forearm from the apex of this triangle the sinuous dorsal border of the ulna can be felt in its whole length: above, it is situated in the middle of the back of the limb; but below, where it is rounded off, it may be traced to the small subcutaneous surface of the styloid process on the medial side of the wrist. The styloid process forms a prominent tubercle continuous above with the dorsal border and ending below in a blunt apex at the level of the wrist-joint; it is most evident when the hand is in a position midway between supination and pronation. When the forearm is pronated the head of the ulna projects on the back of the wrist; between the head and styloid process of the ulna is the groove which lodges the tendon of the *Extensor carpi ulnaris*.

Below the lateral epicondyle of the humerus a portion of the head of the *radius* is palpable; its position is indicated on the surface by a little dimple which is best seen when the arm is extended. If the finger be placed in this dimple and the semiflexed forearm pronated and supinated the head of the radius will be felt rotating in the radial notch. The upper half of the body of the bone is obscured by muscles; the lower half can be readily examined, and when traced downwards

is found to end in a lozenge-shaped convex surface on the lateral side of the base of the styloid process; this is the only subcutaneous part of the bone, and from its lower end the apex of the styloid process bends medialwards towards the wrist. The styloid process of the radius is about 1.25 cm. below the level of the styloid process of the ulna. About the middle of the dorsal surface of the lower end of the radius is the dorsal radial tubercle, best perceived when the wrist is slightly flexed; it forms the lateral boundary of the oblique groove in which the tendon of the *Extensor pollicis longus* lies.

On the front of the wrist are two subcutaneous eminences, one, on the radial side, the larger and flatter, produced by the tuberosity of the *navicular* bone, and the ridge on the *greater multangular* bone; the other, on the ulnar side, by the *pisiform* bone. The tuberosity of the navicular is distal and medial to the styloid process of the radius, and is most clearly visible when the wrist-joint is extended; the ridge on the greater multangular is about 1 cm. distal to it. The pisiform is about 1 cm. distal to the lower end of the ulna, and just distal to the level of the styloid process of the radius; it is crossed by the uppermost of the three transverse skin furrows on the front of the wrist. The rest of the volar surface of the carpus is covered by tendons and the transverse carpal ligament, and is entirely concealed, with the exception of the hamulus of the *hamate bone*, which however, is difficult to define. On the dorsal surface of the carpus the *triquetral bone* can be clearly made out, and when the wrist-joint is acutely flexed the head of the capitate bone may be felt.

The dorsal surfaces of the *metacarpal bones*, except that of the fifth, are covered by the extensor tendons, and are visible only in very thin hands; the dorsal surface of the fifth is, however, subcutaneous throughout almost its whole length. Slightly lateral to the middle line of the hand is a prominence, frequently well marked, formed by the styloid process of the third metacarpal bone; it is situated about 4 cm. distally to the dorsal radial tubercle. The heads of the metacarpal bones are rounded in contour and stand out in bold relief under the skin when the fist is clenched; the head of the third is the most prominent. In the palm of the hand the metacarpal bones of the fingers are covered by muscles, tendons, and aponeuroses, so that only their heads can be distinguished. The base of the metacarpal bone of the thumb, however, is prominent dorsally, and the body of the bone is easily palpable, ending at the head in a flattened prominence in front of which are the sesamoid bones.

The enlarged ends of the *phalanges* can be easily felt. When the digits are flexed, a slight concavity can be recognised on the distal end of each of the first phalanges; the distal ends of the second phalanges are flattened and square-shaped.

Articulations.—The *sternoclavicular joint* is subcutaneous, and its position is indicated by the enlarged sternal extremity of the clavicle, lateral to the long cord-like sternal head of *Sternocleidomastoideus*. If this muscle be relaxed a depression between the end of the clavicle and the sternum can be felt, defining the exact position of the joint.

The position of the *acromioclavicular joint* is ascertained by determining the slightly enlarged acromial end of the clavicle which projects above the level of the acromion; sometimes this enlargement is so considerable as to form a rounded eminence. The *shoulder-joint* is deeply seated and cannot be palpated.

When the forearm is slightly flexed a curved crease or fold with its convexity downwards is seen in front of the elbow, extending from one epicondyle to the other; the *elbow-joint* is slightly distal to the centre of the fold. The position of the radiohumeral part of the joint can be ascertained by feeling for a slight groove or depression between the head of the radius and the capitulum of the humerus, at the back of the elbow-joint.

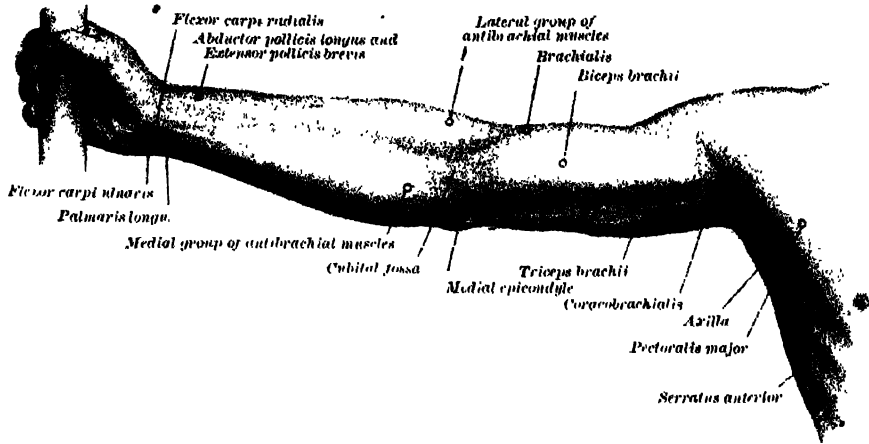
The position of the *proximal radio-ulnar joint* is marked on the surface at the back of the elbow by the dimple which indicates the position of the head of the radius. The site of the *distal radio-ulnar joint* can be defined by feeling for the slight groove at the back of the wrist, between the prominent head of the ulna and the lower end of the radius, when the forearm is in a state of almost complete pronation.

Of the three transverse skin furrows on the front of the wrist, the middle corresponds fairly accurately with the *radiocarpal* or *wrist-joint*, and the most distal indicates the position of the *midcarpal articulation*.

The *metacarpophalangeal* and *interphalangeal* joints are readily available for surface examination; the former are situated just distally to the prominences of the knuckles, the latter are sufficiently indicated by the furrows on the volar, and the wrinkles on the dorsal, surfaces.

Muscles (figs. 1153, 1154).—The anterior border of the *Trapezius* presents as a slight ridge running downwards and forwards from the superior nuchal line of

FIG. 1153.—Front of right upper extremity.

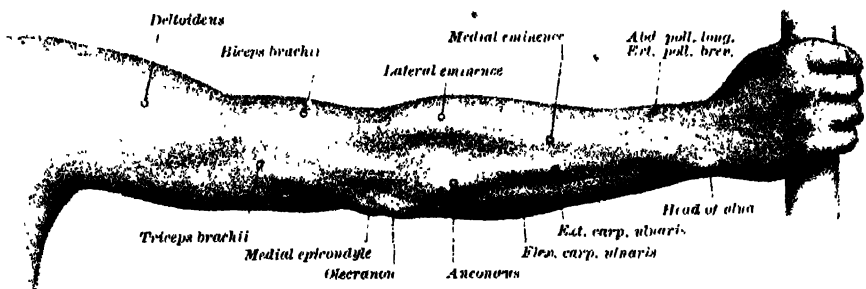


the occipital bone to the junction of the intermediate with the lateral third of the clavicle. The inferior border of the muscle forms an undulating ridge passing downwards and medialwards from the root of the spine of the scapula to the spinous process of the twelfth thoracic vertebra.

The lateral border of the *Latissimus dorsi* (fig. 1139) may be traced, when the muscle is in action, as a rounded edge starting from the iliac crest and slanting obliquely forwards and upwards to the axilla, where it takes part with the *Teres major* in forming the posterior axillary fold.

The *Pectoralis major* (fig. 1143) conceals a considerable part of the thoracic wall in front. Its sternal origin presents a border which bounds and determines the width of the sternal furrow. The upper margin is generally well marked near the clavicle, and forms the medial boundary of the infraclavicular fossa, which

FIG. 1154.—Back of right upper extremity.



separates the *Pectoralis major* from the *Deltoides*; it gradually becomes less distinct as it approaches the tendon of insertion and cannot be differentiated from the *Deltoides*. The lower border of the *Pectoralis major* forms the rounded anterior axillary fold. Occasionally a gap is visible between the clavicular and sternal parts of the muscle.

When the arm is raised the lowest slip of origin of the *Pectoralis minor* produces a fulness below the anterior axillary fold and serves to break the sharp outline of the lower border of the *Pectoralis major*.

The origin of the *Serratus anterior* (figs. 1139, 1143) causes a very characteristic surface marking. When the arm is abducted the lower five or six serrations can be seen, separated from those of the *Obliquus externus abdominis* by a zigzag line. When the arm is by the side the highest visible serration is that attached to the fifth rib.

The *Deltoideus* with the underlying prominence of the upper end of the humerus produces the rounded contour of the shoulder; it is rounder and fuller in front than behind, where it presents a somewhat flattened form. Above, its anterior border presents a slightly curved eminence which forms the lateral boundary of the infraclavicular fossa; below, it is closely united with the *Pectoralis major*. Its posterior border is thin, flattened, and scarcely marked above, but is thicker and more prominent below. The insertion of the *Deltoideus* is marked by a depression on the lateral side of the middle of the arm.

Of the scapular muscles the *Teres major* assists the *Latissimus dorsi* to form the thick, rounded, posterior axillary fold.

When the arm is raised the *Coracobrachialis* appears as a narrow elevation emerging from under cover of the anterior axillary fold and running medially to the upper half of the body of the humerus.

On the front and medial aspects of the arm is the prominence of the *Biceps brachii*, bounded on either side by a depression. It determines the contour of the front of the arm and extends from the anterior axillary fold to the bend of the elbow; its upper tendons are concealed by the *Pectoralis major* and *Deltoideus*, and its lower tendon sinks into the cubital fossa. When the muscle is fully contracted it presents a globular form, and the *lacertus fibrosus* (bicipital fascia) attached to its tendon of insertion becomes prominent as a sharp ridge running downwards and medialwards.

On either side of the *Biceps brachii* at the lower part of the arm the *Brachialis* is discernible. Laterally it forms a narrow eminence extending some distance up the arm; medially it produces only a slight fulness above the elbow.

On the back of the arm the long head of the *Triceps brachii* may be seen as a longitudinal eminence, emerging from under cover of *Deltoideus* and gradually passing into the flattened plane of the tendon of insertion of the muscle at the lower part of the back of the arm. When the muscle is in action its medial and lateral heads are prominent.

On the front of the elbow are two muscular elevations, one on either side, which converge below and form the medial and lateral boundaries of the cubital fossa. The medial elevation consists of the *Pronator teres* and the flexors, and is fusiform, pointed above at the medial epicondyle, and gradually tapering off below. The *Pronator teres* is the most lateral of the group, while the *Flexor carpi radialis*, lying to its medial side, is the most prominent and may be traced downwards to its tendon, which is situated nearer to the lateral than to the medial border of the front of the wrist, where it is placed on the medial side of the radial artery and on the lateral side of the median nerve. The *Palmaris longus* presents no surface marking above, but below, its tendon stands out when the muscle is in action as a sharp cord in front of the middle of the wrist. The *Flexor digitorum sublimis* does not directly influence surface form; the position of its four tendons on the front of the lower part of the forearm is indicated by an elongated depression between the tendon of the *Palmaris longus* and that of the *Flexor carpi ulnaris*. The *Flexor carpi ulnaris* determines the contour of the medial border of the forearm, and is separated from the extensor group of muscles by the ulnar furrow the floor of which is formed by the subcutaneous dorsal border of the ulna; its tendon is evident along the ulnar border of the lower part of the forearm, and is most marked when the hand is flexed and adducted.

The elevation on the lateral side of the cubital fossa is produced by the *Brachioradialis*, the extensors, and the *Supinator*; it occupies the lateral and a considerable part of the dorsal surface of the forearm in the region of the elbow, and appears as a fusiform swelling which is on a higher level than that produced by the medial elevation. Its apex is between the *Triceps brachii* and *Brachialis* some distance above the elbow-joint; its greatest breadth is opposite the lateral epicondyle; below this it shades off into a flattened surface. About the middle of the forearm it divides into a lateral and a medial eminence. The lateral eminence consists of the *Brachioradialis*, the *Extensor carpi radialis longus* and the *Extensor carpi radialis brevis*. The medial border of the *Brachioradialis* starts as a rounded

elevation above the lateral epicondyle; lower down, the muscle forms a prominent mass on the radial side of the upper part of the forearm; below, it tapers to its tendon, which may be traced to the base of the styloid process of the radius. The medial eminence comprises the *Extensor digitorum communis*, *Extensor digiti quinti proprius*, and the *Extensor carpi ulnaris*; it begins at the lateral epicondyle of the humerus as a tapering mass which is separated above from the *Anconæus* by a well-marked groove, and below from the *Flexor carpi ulnaris* by the ulnar furrow. The *Anconæus* produces a triangular, slightly elevated area, immediately lateral to the subcutaneous surface of the olecranon and separated from the extensor group by an oblique depression; the upper angle of the triangle is at the dimple behind the lateral epicondyle.

At the lower part of the back of the forearm in the interval between the lateral and medial eminences is an oblique elongated swelling, full above but flattened and partially subdivided below; it is caused by the *Abductor pollicis longus* and the *Extensor pollicis brevis*. It crosses the dorsal and lateral surfaces of the radius to the lateral side of the wrist-joint, whence it is continued to the dorsal surface of the thumb as a ridge which is best marked when the thumb is extended.

The tendons of most of the extensor muscles can be seen and felt on the back of the wrist. Laterally is the oblique ridge produced by the *Extensor pollicis longus*. When the wrist is extended the *Extensor carpi radialis longus* and the *Extensor carpi radialis brevis* can be identified, the one on the lateral and the other on the medial side of the tendon of the *Extensor pollicis longus*. Medially to this the extensor tendons of the fingers can be felt, the *Extensor digiti quinti proprius* being separated from those of the *Extensor digitorum communis* by a slight furrow.

The muscles of the hand are principally concerned, as regards surface form, in producing the thenar and hypothenar eminences, and cannot be individually distinguished; the thenar eminence, on the lateral side, is larger and rounder than the hypothenar, which is a long narrow elevation along the medial side of the palm. When the *Palmaris brevis* is in action it produces a wrinkling of the skin over the proximal part of the hypothenar eminence and a dimple on the medial border of the hand. On the back of the hand the *Interossei dorsales* give rise to elongated swellings between the metacarpal bones; the first forms a prominent fusiform bulging when the thumb is adducted, the others are not so marked.

Arteries.—Above the middle of the clavicle the pulsation of the *subclavian artery* can be detected by pressing downwards, backwards, and medialwards against the first rib. The pulsation of the *axillary artery*, where the vessel crosses the second rib, can be felt below the middle of the clavicle medially to the coracoid process; along the lateral wall of the axilla the course of the artery can be easily followed close to the medial border of the *Coracobrachialis*. The *brachial artery* can be recognised along the medial margin of the *Biceps brachii*; in the upper two-thirds of the arm it lies on the medial side of the humerus, but in the lower third is more directly in front of the bone. In front of the lower end of the radius, between the styloid process and *Flexor carpi radialis*, a portion of the *radial artery* is superficial and is used clinically for observations on the pulse.

Veins.—The superficial veins of the upper extremity are easily rendered visible by compressing the proximal trunks near the axilla; their arrangement is described on pp. 687 to 689.

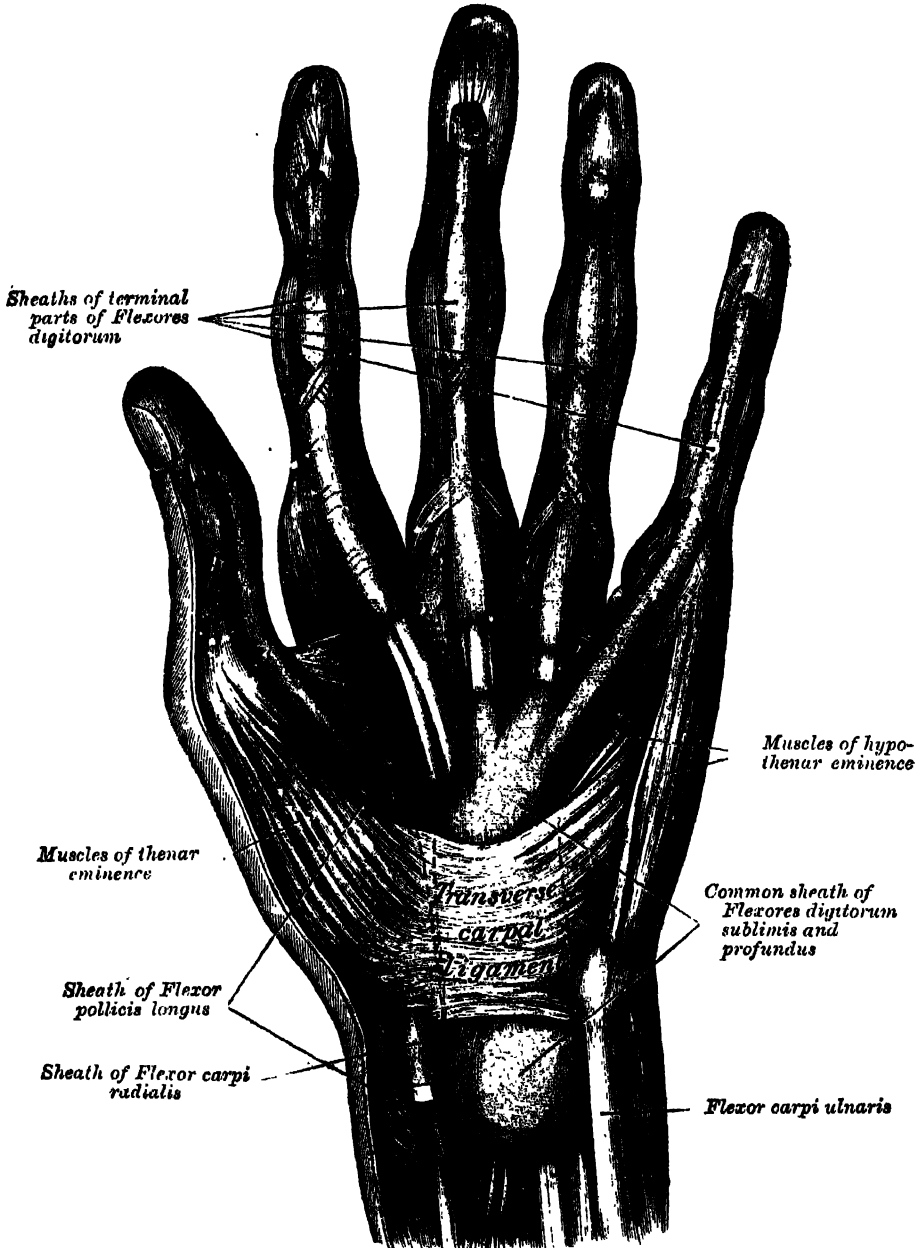
Nerves.—The uppermost trunks of the *brachial plexus* can be felt for a short distance above the clavicle as they emerge from under the lateral border of *Sternocleidomastoideus*; the larger nerves derived from the plexus can be rolled under the finger against the lateral axillary wall, but cannot be separately identified. The *ulnar nerve* can be detected in the sulcus *nervi ulnaris* behind the medial epicondyle of the humerus, but is more easily felt about 2 cm. below the elbow-joint.

SURFACE MARKINGS OF THE UPPER EXTREMITY

Bony landmarks.—The bony landmarks as described above are so readily available for surface recognition that no special measurements are required to indicate them. It may be noted, however, that the medial angle of the scapula is applied to the second rib, while the inferior angle lies against the seventh. The intertubercular sulcus of the humerus is below the acromioclavicular joint when the arm hangs by the side of the body with the palm of the hand forwards.

Articulations.—The *acromioclavicular joint* is situated in a plane passing sagittally through the middle line of the front of the arm. The line of the *elbow-joint* is not straight; the humeroradial portion is practically at right angles to the long axis of the humerus, and is situated about 2 cm. distally to the lateral epicondyle;

FIG. 1155.—The mucous sheaths of the tendons on the front of the wrist and digits.

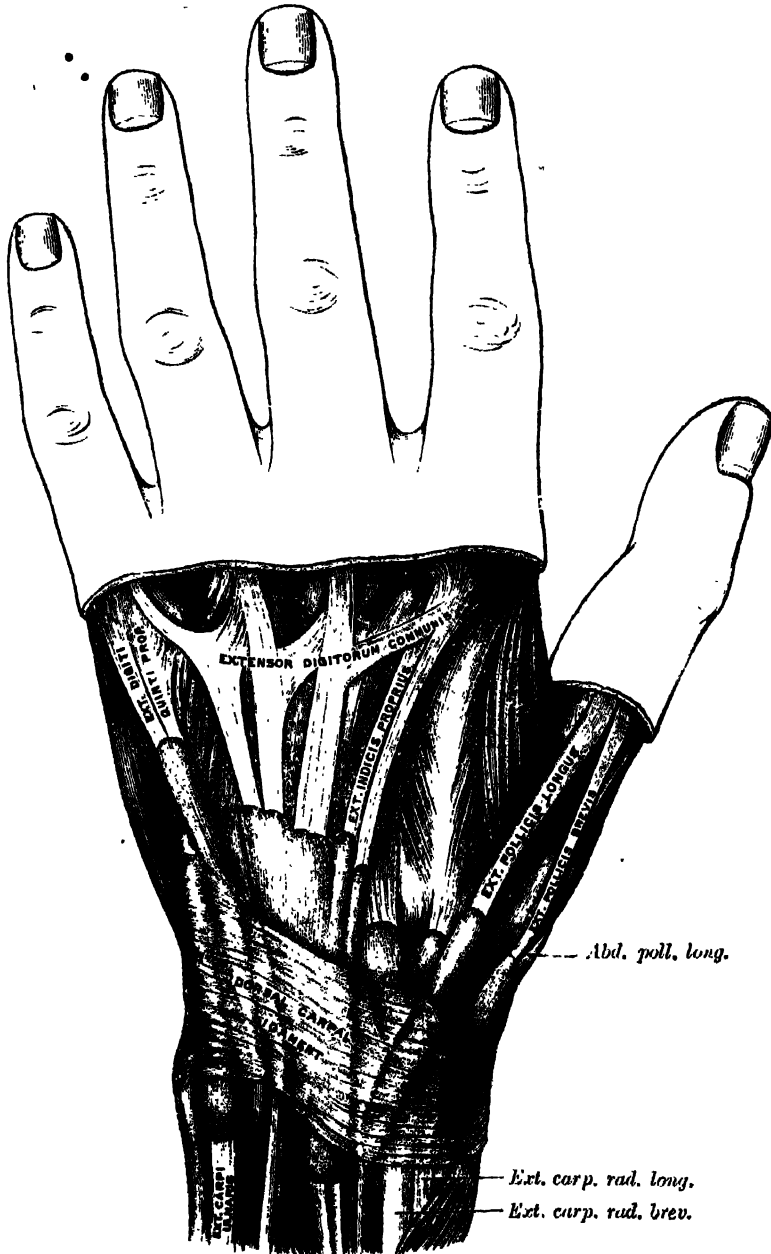


the humero-ulnar portion is oblique, and its medial end is about 2.5 cm. distally to the medial epicondyle. The position of the *wrist-joint* can be indicated by drawing a curved line, with its convexity upwards, between the styloid processes of the radius and ulna; the summit of the convexity is about 1 cm. above the centre of a straight line joining the two processes.

Muscles.—The only muscles of the upper extremity which occasionally require definition by surface lines are the Trapezius, the Latissimus dorsi and the Pectorales

major and minor. The anterosuperior border of the *Trapezius* is indicated by a line from a point about 3 cm. laterally to the external occipital protuberance to the junction of the intermediate with the lateral third of the clavicle; the line of the lower border extends from the spinous process of the twelfth thoracic vertebra

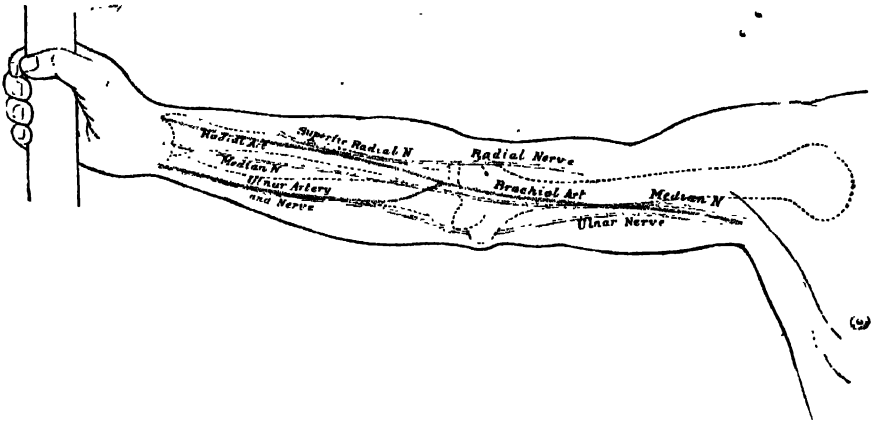
FIG. 1156.—The mucous sheaths of the tendons on the back of the wrist.



to the root of the spine of the scapula. The upper border of the *Latissimus dorsi* is almost horizontal, running from the spinous process of the seventh thoracic vertebra to the inferior angle of the scapula and thence somewhat obliquely to the intertubercular sulcus of the humerus; the lower border corresponds roughly to a line drawn from the iliac crest about 2 cm. from the lateral margin of the *Sacrospinalis* to the intertubercular sulcus of the humerus. The upper margin of the *Pectoralis major* extends from the middle of the clavicle to the surgical neck

of the humerus ; its lower border is practically in the line of the fifth rib and reaches from the fifth costochondral junction to the middle of the anterior border of the Deltoides. The lines indicating the upper and lower borders of the *Pectoralis minor* begin at the coracoid process of the scapula and extend to the third and fifth ribs respectively, just laterally to the corresponding costal cartilages. On

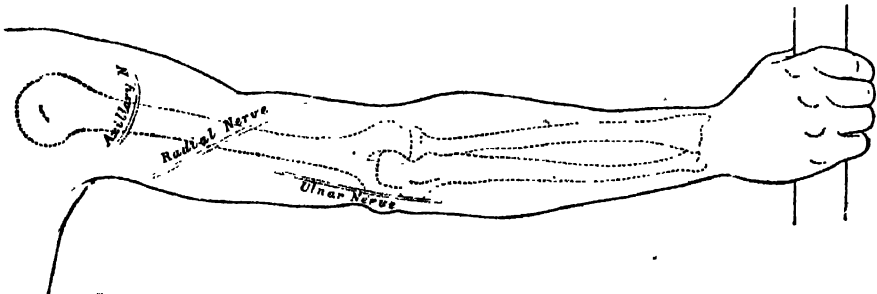
FIG. 1157.—Front of right upper extremity, showing surface markings for bones, arteries, and nerves.



the front of the elbow-joint a triangular space—the cubital fossa—is mapped out for convenience of reference. The base of the triangle is a line joining the medial and lateral epicondyles of the humerus, while the sides are formed respectively by the salient margins of the Brachioradialis and Pronator teres.

Mucous sheaths.—On the volar surfaces of the wrist and hand the mucous sheaths of the flexor tendons (fig. 1155) can be indicated as follows. The sheath for the Flexor pollicis longus extends from a point about 3 cm. above the upper edge of the transverse carpal ligament to the terminal phalanx of the thumb. The common sheath for the tendons of the Flexor digitorum sublimis and Flexor digitorum profundus reaches about 4 cm. above the upper edge of the transverse carpal ligament, and extends into the palm to about the level of the centres of the metacarpal bones. The sheath for the tendons to the little finger is continued from the common sheath

FIG. 1158.—Back of right upper extremity, showing surface markings for bones and nerves.



to the base of the terminal phalanx of this finger ; the sheaths of the tendons to the index, middle and ring fingers are separated from the common sheath by an interval ; they begin opposite the necks of the metacarpal bones and extend to the terminal phalanges. The mucous sheaths of the extensor tendons are shown in fig. 1156 (see also pp. 503, 504).

Arteries (fig. 1157).—The course of the *axillary artery* can be indicated by abducting the arm to a right angle and drawing a line from the middle of the clavicle to the point where the tendon of the Pectoralis major crosses the prominence of

the Coracobrachialis. Of the branches of the axillary artery, the origin of the *thoraco-acromial* corresponds to the point where the axillary artery is crossed by the upper border of the Pectoralis minor; the *lateral thoracic* follows the line of the lower border of the Pectoralis minor; the *subscapular* is sufficiently indicated by the axillary border of the scapula; the *scapular circumflex* is given off the subscapular opposite the midpoint of a line joining the tip of the acromion to the lower edge of the deltoid tuberosity, while the *humeral circumflex* arteries arise from the axillary artery about 2 cm. above this. The course of the *brachial artery* is marked by a line drawn from the medial border of the Coracobrachialis at the level of the posterior axillary fold to a point in front of the elbow-joint midway between the epicondyles of the humerus, and continued distally for 2.5 cm., where the artery bifurcates. With regard to the branches of the brachial artery—the *arteria profunda brachii* crosses the back of the humerus at the level of the insertion of Deltoides; the *nutrient artery* arises opposite the middle of the body of the humerus; a line from this point to the back of the medial epicondyle represents the *superior ulnar collateral artery*; the *inferior ulnar collateral artery* arises about 5 cm. above the fold of the elbow-joint and runs medialwards.

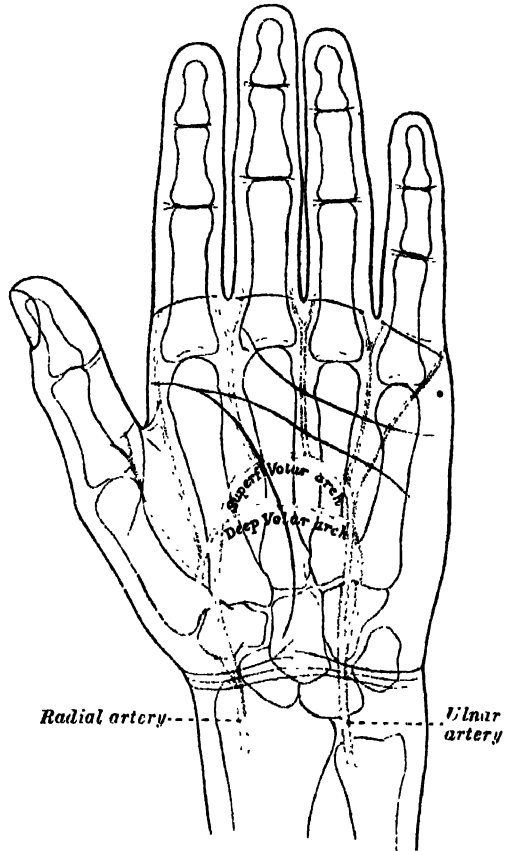
The position of the *radial artery* in the forearm is represented by a line from the lateral margin of the tendon of the Biceps brachii in the centre of the cubital fossa, to the medial side of the front of the styloid process of the radius. The situation of the distal portion of the artery is indicated by continuing this line round the radial side of the wrist to the proximal end of the first intermetacarpal space.

On account of the curved direction of the *ulnar artery*, two lines are required to indicate its course in the forearm; one is drawn from the front of the medial epicondyle of the humerus to the radial side of the pisiform bone; the distal two-thirds of this line represent the distal two-thirds of the artery; the proximal third is represented by a line, convex medialwards, from the centre of the hollow in front of the elbow-joint to the junction of the upper with the middle third of the first line.

The position of the *superficial volar arch* (fig. 1159) is indicated by a line starting from the radial side of the pisiform bone, running distalwards for about one-half of the length of the palm, and then lateralwards as far as the base of the thumb, with its convexity towards the fingers. The summit of the arch is usually on a level with the distal border of the outstretched thumb. The *deep volar arch* is transverse in direction, and is situated about 1 cm. nearer to the carpus.

Nerves (figs. 1157, 1158).—In the arm the line of the *median nerve* is that for the brachial artery; at the upper part of the arm it is lateral to the artery, whereas at the bend of the elbow it is medial to it. The course of the nerve in the forearm is marked by a line starting from a point just medially to the centre of one joining the epicondyles, and extending to the lateral margin of the tendon of the Palmaris longus at the wrist.

FIG. 1159.—Palm of left hand, showing position of skin creases and bones, and surface markings for the volar arches.



The *ulnar nerve* follows the line of the brachial artery in the upper half of the arm, but at the middle of the arm it leaves the artery and descends to the back of the medial epicondyle. In the forearm it is represented by a line from the front of the medial epicondyle to the lateral side of the pisiform bone.

The course of the *radial nerve* can be indicated by a line drawn from just below the posterior axillary fold, to the lateral side of the humerus at the junction of its middle with its lower third; thence it passes vertically downwards on the front of the arm to the level of the lateral epicondyle. The course of the *superficial radial nerve* is represented by a continuation of this line to the junction of the middle with the lower third of the radius; it then crosses the lateral border of the radius and runs distalwards to the dorsum of the base of the first metacarpal bone.

The *axillary nerve* crosses the humerus about 2 cm. above the centre of a line joining the tip of the acromion to the lower edge of the deltoid tuberosity.

SURFACE ANATOMY OF THE LOWER EXTREMITY

Skin.—The skin on the medial side of the thigh and in the hollow of the groin is thin, smooth, and elastic, and contains few hairs except in the neighbourhood of the os pubis; on the lateral side of the thigh it is thicker and the hairs are more numerous. At the junction of the front of the thigh with the abdomen is a well-defined furrow which indicates the site of the inguinal ligament; the furrow presents a general convexity downwards, but its medial half, which is the better marked, is nearly straight. The skin of the buttock is fairly thick and as a rule is destitute of conspicuous hairs except towards the post-anal furrow, where in some males they are abundantly developed. An almost transverse fold—the *fold of the buttock* or *gluteal fold*—crosses the lower part of the buttock; it practically bisects the lower margin of the Glutæus maximus and is most evident when the hip-joint is extended. The skin over the front of the knee is covered by thickened epidermis; it is loose and is thrown into transverse wrinkles when the leg is extended. The skin of the leg is thin, especially on the medial side, and is covered with numerous large hairs. On the dorsum of the foot the skin is thin, loosely connected to subjacent parts, and contains few hairs; on the plantar surface, and especially over the heel, the epidermis is of great thickness, and here, as in the palm of the hand, there are neither hairs nor sebaceous glands.

Bones.—The *hip-bones* are largely covered with muscles, and only approach the surface at a few points. In front, the anterior superior iliac spine is easily recognised, and in thin subject, stands out as a prominence at the lateral end of the fold of the groin; in fat subjects its position is indicated by an oblique depression, at the bottom of which the bony process can be felt. Proceeding upwards and backwards from the anterior superior iliac spine the sinuously curved iliac crest can be traced to the posterior superior iliac spine, the site of which is indicated by a slight depression; on the outer lip of the crest, about 5 cm. behind the anterior superior spine, is the iliac tubercle. In thin subjects the pubic tubercle is very apparent, but in the obese it is obscured by the pubic fat; it can, however, be detected by following the tendon of origin of the Adductor longus. Another part of the hip-bone which is accessible to touch is the ischial tuberosity, situated beneath the Glutæus maximus, and easily felt when the hip-joint is flexed, as it is then uncovered by muscle.

The *femur* is enveloped by muscles, so that the only subcutaneous parts of it are the lateral surface of the greater trochanter and the lower expanded end of the bone. The site of the greater trochanter is generally indicated by a depression owing to the thickness of the Glutæus medius and Glutæus minimus which project above it; when, however, the thigh is flexed, and especially if it be crossed over the opposite one, the trochanter produces a blunt eminence on the surface. The lateral condyle is more easily felt than the medial; both epicondyles can be readily identified, and at the upper part of the medial condyle the sharp adductor tubercle can be recognised without difficulty. When the knee is flexed a portion of the patellar surface of the femur is uncovered and is palpable.

The anterior surface of the *patella* is subcutaneous. When the knee is extended the medial border of the bone is a little more prominent than the lateral, and if the Quadriceps femoris be relaxed the bone can be moved from side to side. When

the joint is flexed the patella recedes into the hollow between the femoral condyles and the upper end of the tibia, and is firmly applied to the femur.

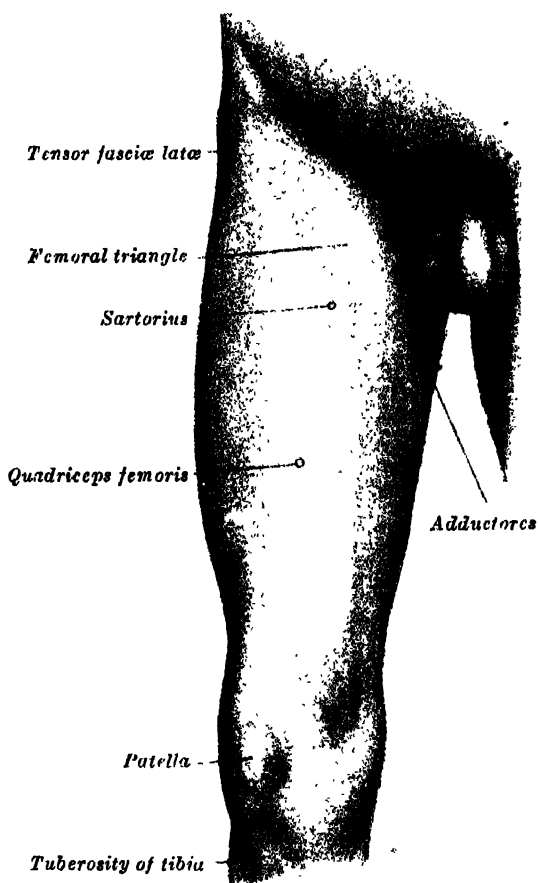
A considerable portion of the *tibia* is subcutaneous. At the upper end the condyles can be felt just below the knee; the medial condyle is broad and smooth, and merges below into the subcutaneous surface of the body or shaft of the bone; the lateral is narrower and more prominent, and on it, about midway between the apex of the patella and the head of the fibula, is the tubercle for the attachment of the iliotibial tract of the fascia lata of the thigh. In front of the upper end of the bone, between the condyles, is the tuberosity, which is continuous below with the anterior crest of the bone. This crest can be identified in the upper two-thirds of its extent as a flexuous ridge, but in the lower third it disappears and the bone is concealed by the tendons of the muscles on the front of the leg. Medially to the anterior crest is the broad subcutaneous surface. The medial malleolus forms a broad prominence, situated at a higher level and somewhat farther forward than the lateral malleolus; its anterior border is nearly straight; on its posterior is a sharp edge which forms the medial margin of the groove for the tendon of the Tibialis posterior.

The only subcutaneous parts of the *fibula* are the head, the lower part of the body or shaft, and the lateral malleolus. The head lies behind and laterally to the lateral condyle of the tibia, and appears as a small prominent pyramidal eminence slightly above the level of the tibial tuberosity; its position can be readily located by following the tendon of Biceps femoris downwards. The lateral malleolus is a narrow elongated prominence from which the lower third or half of the lateral surface of the body of the bone can be traced upwards.

On the dorsum of the tarsus the individual bones cannot be distinguished, with the exception of the head of the *talus* which forms a rounded projection in front of the ankle-joint when the foot is extended. The whole dorsal surface of the foot has a smooth convex outline, the summit of which is the ridge formed by the head of the talus, the navicular, the second cuneiform, and the second metatarsal bone; from this it inclines gradually lateralwards, and rapidly medialwards. On the medial side of the foot the medial process of the tuberosity of the *calcaneus* and the ridge separating the posterior from the medial surface of the bone are distinguishable; in front of this, and below the medial malleolus, is the sustentaculum tali. The tuberosity of the *navicular* is palpable about 2.5 cm. in front of the medial malleolus.

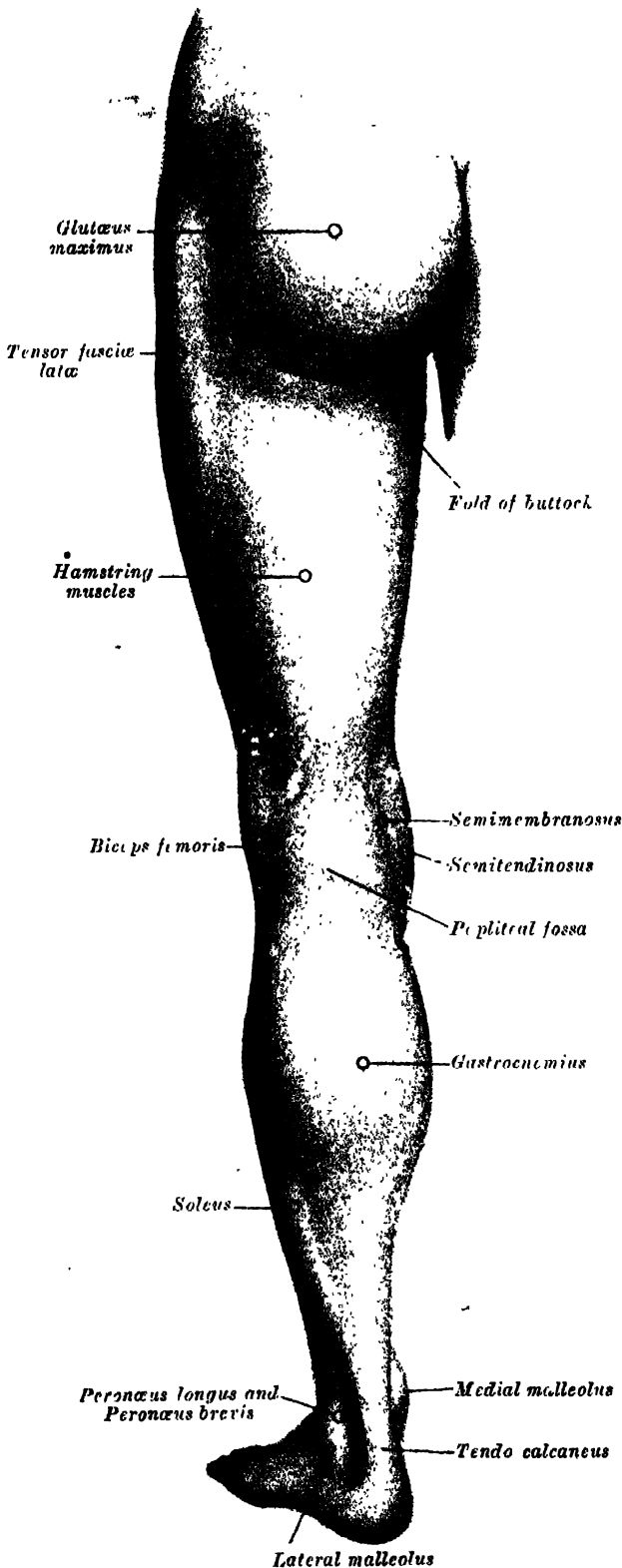
Farther forwards, the ridge formed by the base of the *first metatarsal* bone can be obscurely felt, and from this the body of the bone can be traced to the expanded

FIG. 1160.—Front and medial aspect of right thigh.



head: beneath the base of the first phalanx is the medial sesamoid bone. On

FIG. 1161.—Back of left lower extremity.



the lateral side of the foot, the most posterior bony point is the lateral process of the tuberosity of the calcaneus, with the ridge separating the posterior from the lateral surface of the bone. In front of this the greater part of the lateral surface of the calcaneus is subcutaneous; on it, below and in front of the lateral malleolus, the trochlear process, when present, can be felt. Farther forwards the base of the fifth metatarsal bone is prominent, and from it the body of the bone can be traced forwards to the head.

As in the case of the metacarpals, the dorsal surfaces of the metatarsal bones are easily defined, although their heads do not form prominences: the plantar surfaces are obscured by muscles. The phalanges in their whole extent are readily palpable.

Articulations. -- The hip-joint is deeply seated and cannot be palpated.

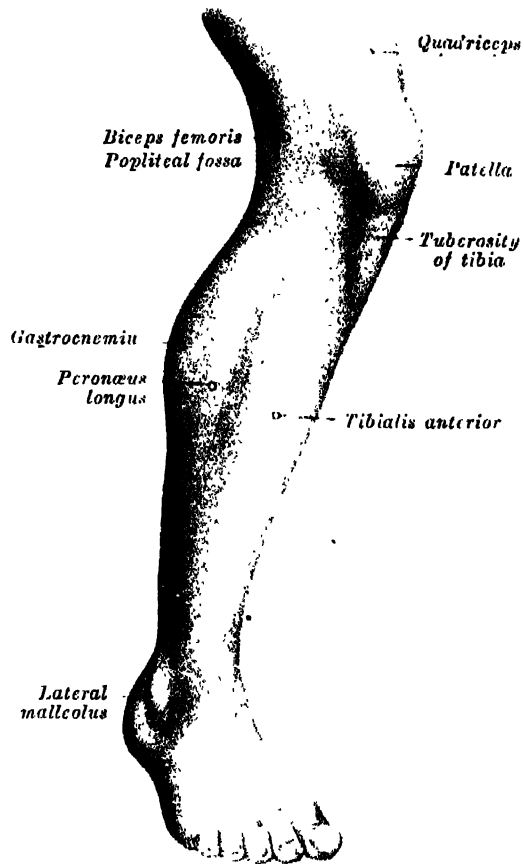
The interval between the tibia and femur, indicating the level of the knee-joint, can always be easily felt. When the knee is semi-flexed, the medial border of the patella, the medial condyle of the femur, and the upper border of the medial condyle of the tibia, bound a triangular depressed area which indicates the position of the joint and is in front of the anterior end of the medial meniscus.

The ankle-joint can be felt on either side of the Extensor tendons, and during extension of the joint the superior articular surface of the talus projects below the anterior border of the lower end of the tibia.

Muscles.—Of the muscles of the thigh, those of the anterior femoral region (fig. 1160) contribute largely to surface form. The *Tensor fasciæ latæ* produces a broad elevation immediately below the anterior part of the iliac crest and behind the anterior superior iliac spine; from its lower border a groove caused by the iliotibial tract of the fascia lata extends downwards to the lateral side of the knee-joint. The upper portion of the *Sartorius* constitutes the lateral boundary of the femoral triangle, and, when the muscle is in action, forms a prominent oblique ridge which is continued below into a flattened plane and then gradually merges into a general fulness on the medial side of the knee-joint. When the *Sartorius* is not in action, a depression exists between the *Quadriceps femoris* and the *Adductores* and extends obliquely downwards and medialwards from the apex of the femoral triangle to the side of the knee. In the angle between the *Sartorius* and *Tensor fasciæ latæ*, just below the anterior superior iliac spine, the *Rectus femoris* appears, and its borders can be defined when the muscle is in action. The *Vastus lateralis* forms a long flattened plane traversed by the groove of the iliotibial tract. The *Vastus medialis* causes a considerable prominence on the medial side of the lower half of the thigh; this prominence increases towards the knee and ends somewhat abruptly with a full curved outline. The *Vastus intermedius* is completely hidden. The *Adductores* cannot be differentiated from one another, with the exception of the tendon of origin of the *Adductor longus* and the lower tendon of the *Adductor magnus*. When the *Adductor longus* is in action its tendon of origin stands out as a prominent ridge running obliquely downwards and lateralwards from the neighbourhood of the pubic tubercle, and forming the medial border of the femoral triangle. The lower tendon of the *Adductor magnus* is felt as a short ridge extending downwards between the *Sartorius* and *Vastus medialis* to the adductor tubercle on the medial condyle of the femur. The *Adductores* fill the triangular space at the upper part of the thigh, between the femur and the pelvis, and to them is due the contour of the medial border of the thigh, the *Gracilis* contributing largely to the smoothness of the outline.

The *Glutæus maximus* (fig. 1161) forms the full rounded outline of the buttock; it is prominent behind, compressed in front, and ends at its tendinous insertion in a depression immediately behind the greater trochanter; its lower border crosses the glutæal fold obliquely downwards and lateralwards; the lower part of its medial border is separated from the corresponding part of the opposite muscle by the deep glutæal cleft. The upper part of the *Glutæus medius* is visible, but its lower part, together with the *Glutæus minimus* and the external rotators of the thigh, is completely hidden. The hamstring muscles appear from beneath the lower margin of the *Glutæus maximus*; at first they are narrow and not well defined, but as they descend they become more prominent and eventually divide into two well-marked ridges formed by their tendons; these constitute the upper

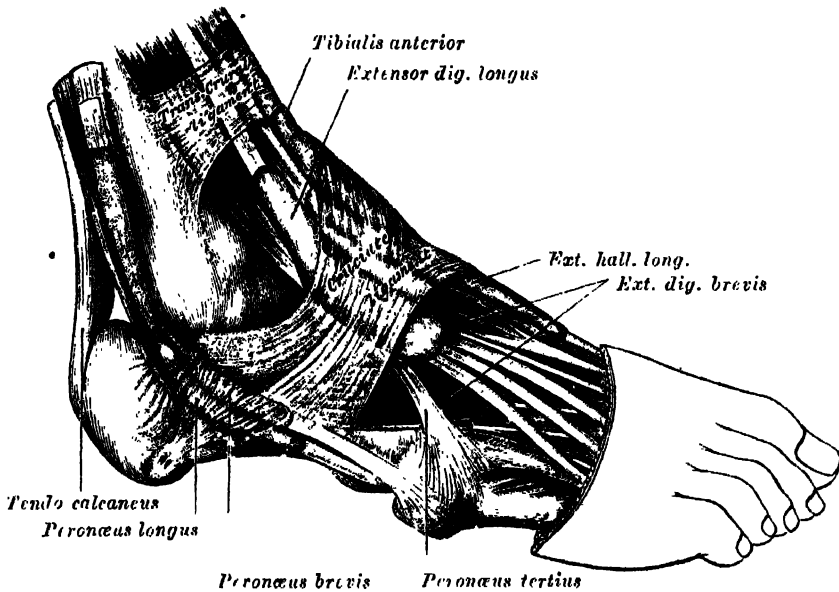
FIG. 1162.—Lateral aspect of right leg.



boundaries of the popliteal fossa. The tendon of the *Biceps femoris* is a thick cord running to the head of the fibula: the tendons of the *Semimembranosus* and *Semitendinosus* run medialwards to the tibia and are separated by a slight furrow; the *Semitendinosus* is the more superficial, and can be felt in certain positions of the limb as a sharp cord, while the *Semimembranosus* is thick and rounded. The *Gracilis* is situated a little in front of them.

The *Tibialis anterior* (fig. 1162) presents a fusiform enlargement at the lateral side of the tibia and projects beyond the anterior crest of the bone; its tendon can be traced on the front of the tibia and ankle-joint and thence along the medial side of the foot to the base of the first metatarsal bone. The fleshy fibres of the *Peronæus longus* are strongly marked at the upper part of the lateral side of the leg: it is

FIG. 1163.—The mucous sheaths of the tendons round the ankle. Lateral aspect.



separated by furrows from the *Extensor digitorum longus* in front and the *Soleus* behind. Below, the fleshy fibres end abruptly in a tendon which overlaps the more flattened elevation of the *Peronæus brevis*; below the lateral malleolus the tendon of the *Peronæus brevis* is the more marked.

On the dorsum of the foot (fig. 1163) the tendons emerging from beneath the transverse and cruciate crural ligaments spread out and can be distinguished as follows: the most medial and largest is the *Tibialis anterior*, the next is the *Extensor hallucis proprius*, then the *Extensor digitorum longus* dividing into four tendons to the second, third, fourth, and fifth toes, and lastly the *Peronæus tertius*. The *Extensor digitorum brevis* produces a rounded outline on the dorsum of the foot and a fulness in front of the lateral malleolus. The *Interossei dorsales* bulge between the metatarsal bones.

At the back of the knee is the popliteal fossa, bounded above by the tendons of the hamstrings and below by the *Gastrocnemius*. Below this fossa is the prominent fleshy mass of the calf of the leg produced by the *Gastrocnemius* and *Soleus* (fig. 1161). When these muscles are in action the borders of the *Gastrocnemius* form two well-defined curved lines which converge to the tendo calcaneus; the medial border is the more prominent. At the same time the edges of the *Soleus* form, on either side of the *Gastrocnemius*, curved eminences, of which the lateral is the longer. The fleshy mass of the calf ends somewhat abruptly in the tendo calcaneus, which tapers in the upper three-fourths of its extent but widens out slightly below. When the *Tibialis posterior* is in action, its tendon produces a well-defined ridge behind the medial border of the lower part of the tibia.

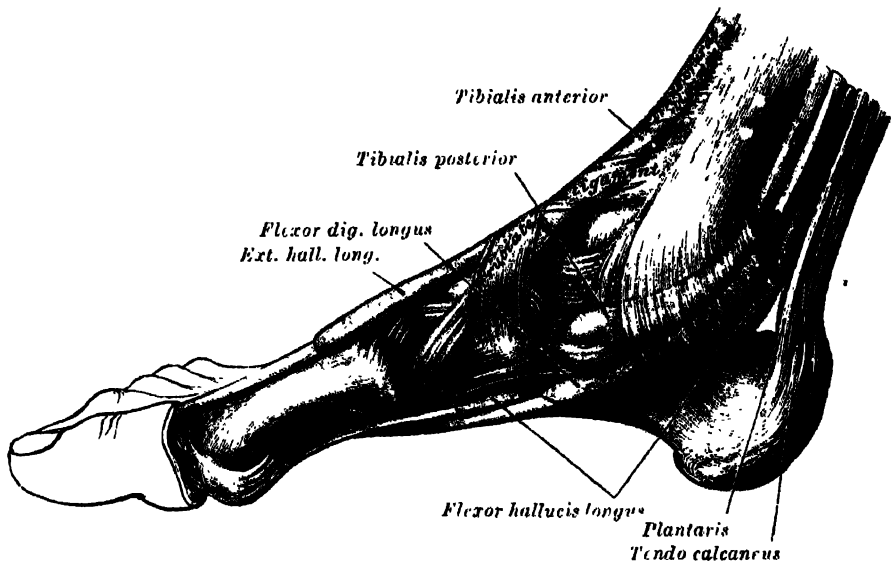
• On the sole of the foot the *Abductor digiti quinti* forms a narrow rounded

elevation on the lateral side, and the *Abductor hallucis* a lesser elevation on the medial side. The *Flexor digitorum brevis*, bound down by the plantar aponeurosis, is not very apparent; it produces a flattened form, and the thickened skin underlying it is thrown into numerous wrinkles.

Arteries.—The *femoral artery* is readily felt as it crosses the brim of the pelvis; in its course down the thigh its pulsation becomes gradually more difficult of recognition. When the knee is flexed the pulsation of the *popliteal artery* can easily be detected in the popliteal fossa.

The *anterior tibial artery* is superficial on the lower part of the front of the tibia and can be traced over the ankle into the *dorsalis pedis artery*: the latter can be followed to the proximal end of the first intermetatarsal space. The pulsation

FIG. 1164.—The mucous sheaths of the tendons round the ankle. Medial aspect.



of the *posterior tibial artery* is evident near the lower end of the back of the tibia, and is easily detected behind the medial malleolus.

Veins.—By compressing the proximal trunks, the venous arch on the dorsum of the foot and the great and small saphenous veins (see pp 695, 696) are rendered visible.

Nerves.—The only nerves of the lower extremity which can be located by palpation are the (1) *common peroneal nerve* as it winds round the lateral side of the neck of the fibula, and (2) the *tibial nerve* as it descends behind the lower end of the tibia.

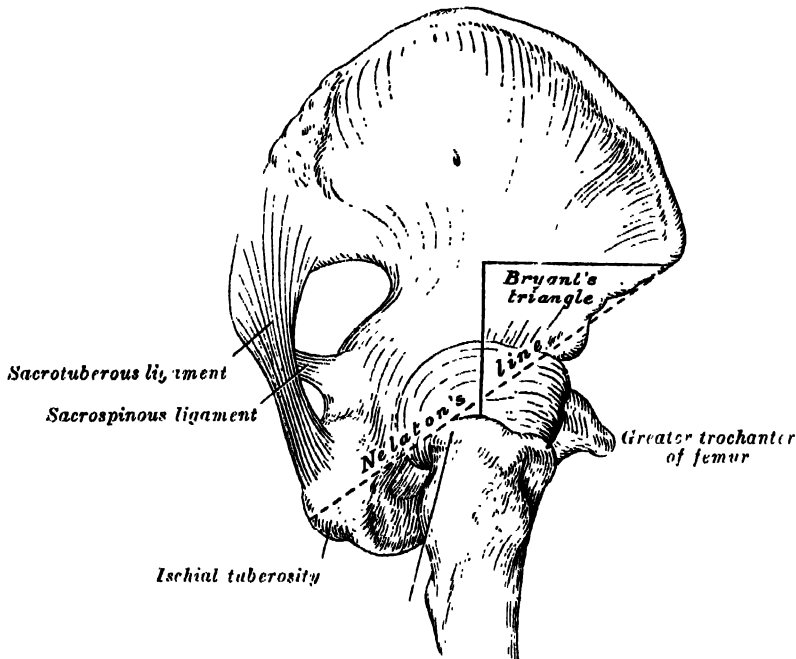
SURFACE MARKINGS OF THE LOWER EXTREMITY

Bony landmarks.—The anterior superior iliac spine is at the level of the sacral promontory—the posterior at the level of the spinous process of the second sacral vertebra. A horizontal line through the highest points of the iliac crests passes also through the spinous process of the fourth lumbar vertebra, while, as already pointed out (p. 1235), the transtubercular plane through the tubercles on the iliac crests cuts the body of the fifth lumbar vertebra. The upper margin of the greater sciatic notch is opposite the spinous process of the third sacral vertebra, and slightly below this level is the posterior inferior iliac spine. The surface markings of the posterior inferior iliac spine and the ischial spine are in a line which joins the posterior superior iliac spine to the outer part of the ischial tuberosity; the posterior inferior spine is 5 cm. and the ischial spine 10 cm. below the posterior superior spine; the ischial spine is opposite the first piece of the coccyx.

With the body in the erect posture the line joining the pubic tubercle to the top of the greater trochanter is nearly horizontal; the middle of this line overlies the acetabulum and the head of the femur.

A line used for clinical purposes is that of Nélaton (fig. 1165), which is drawn from the anterior superior iliac spine to the most prominent part of the ischial tuberosity; it crosses the centre of the acetabulum and the upper border of the greater trochanter. Another surface marking of clinical importance is Bryant's triangle, which is mapped out thus: a line from the anterior superior iliac spine to the top of the greater trochanter forms the base of the triangle; its sides are formed respectively by a horizontal line carried backwards from the anterior superior iliac spine and a vertical line from the top of the greater trochanter.

FIG. 1165.—Nélaton's line and Bryant's triangle.



Articulations.—The posterior superior iliac spine overlies the centre of the *sacro-iliac articulation*.

¶ The *hip-joint* may be indicated, as described above, by the centre of a horizontal line from the pubic tubercle to the top of the greater trochanter; or by a point below and slightly lateral to the middle of the inguinal ligament. The *knee-joint* is superficial and requires no surface marking. The level of the *ankle-joint* is that of a transverse line about 1 cm. above the level of the tip of the medial malleolus. If the foot be extended, the head of the talus appears as a rounded prominence on the medial side of the dorsum; between it and the tuberosity of the navicular is the *talonavicular joint*. The *calcaneocuboid joint* is midway between the lateral malleolus and the prominent base of the fifth metatarsal bone; the line indicating it is parallel to that of the talonavicular joint. The line of the *fifth tarsometatarsal joint* is very oblique; it starts behind the projection of the base of the fifth metatarsal bone, and if continued would pass through the head of the first metatarsal. The lines of the *fourth* and *third tarsometatarsal joints* are less oblique. The *first tarsometatarsal joint* corresponds to a groove which can be felt by making firm pressure on the medial border of the foot 2.5 cm. in front of the tuberosity of the navicular; the position of the *second tarsometatarsal joint* is 1.25 cm. behind this. The *metatarsophalangeal joints* are about 2.5 cm. behind the webs of the corresponding toes.

Muscles.—The muscles do not require surface lines to indicate them, but there are three intermuscular spaces which must be identified, viz.: the femoral triangle, the adductor canal, and the popliteal fossa.

The *femoral triangle* is bounded above by the inguinal ligament, laterally by the medial border of the Sartorius, and medially by the medial border of the Adductor longus. In the triangle is the fossa ovalis (saphenous opening), through which the great saphenous vein dips to join the femoral; the centre of this fossa is about 4 cm. below and lateral to the pubic tubercle, its vertical diameter measures about 4 cm. and its transverse about 1.5 cm. The centre of the femoral ring is about 1.25 cm. lateral to the pubic tubercle.

The *adductor canal* occupies the medial part of the middle third of the thigh; it begins at the apex of the femoral triangle and lies deep to the vertical part of the

FIG. 1166.—Front of right thigh, showing surface markings for bones, femoral artery, and femoral nerve.

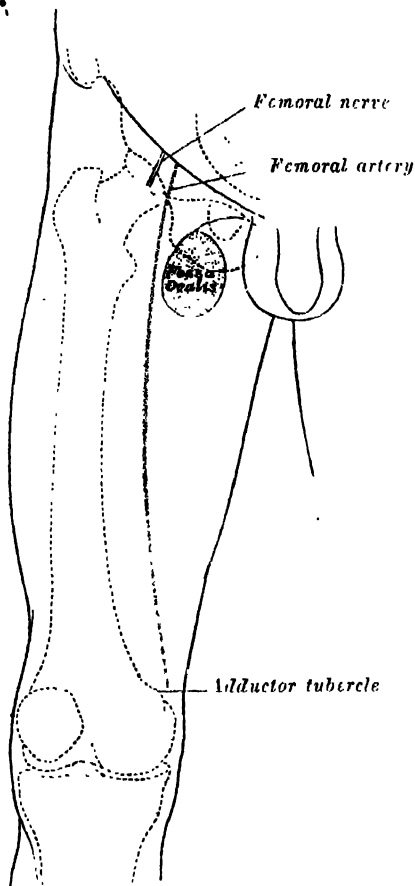
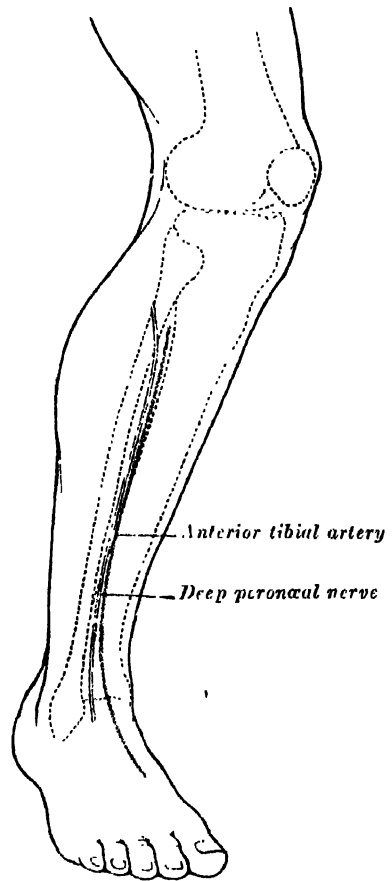


FIG. 1167.—Lateral aspect of right leg, showing surface markings for bones, anterior tibial and dorsalis pedis arteries, and deep peroneal nerve.



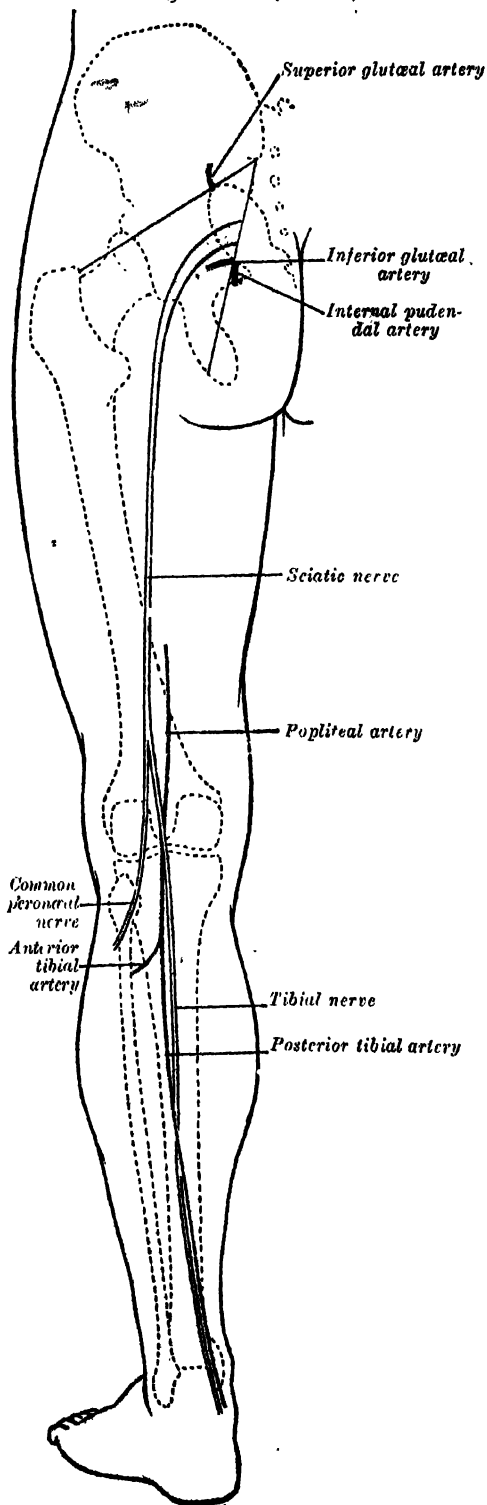
Sartorius. The *popliteal fossa* is bounded, above and medially by the tendons of the Semimembranosus and Semitendinosus, above and laterally by the tendon of the Biceps femoris, below and medially by the medial head of the Gastrocnemius, below and laterally by the lateral head of the Gastrocnemius and the Plantaris.

Mucous sheaths.—The positions of the mucous sheaths round the tendons about the ankle-joints are sufficiently indicated in figs. 1163, 1164 (see also pp. 536, 537).

Arteries.—The points of emergence of the three main arteries on the buttock, viz. the superior and inferior gluteal arteries and the internal pudendal artery, may be indicated in the following manner (fig. 1168). With the femur slightly flexed and rotated inwards, a line is drawn from the posterior superior iliac spine to the posterior superior angle of the greater trochanter; the point of emergence of the *superior gluteal artery* from the upper part of the greater sciatic foramen

corresponds to the junction of the upper with the middle third of this line. A second

FIG. 1168.—Back of left lower extremity, showing surface markings for bones, vessels, and nerves.



line is drawn from the posterior superior iliac spine to the outer part of the ischial tuberosity; the point of emergence of the *inferior gluteal* and *internal pudendal* arteries from the lower part of the greater sciatic foramen corresponds to the junction of its middle with its lower third. The course of the *femoral artery* (fig. 1166) is represented by the upper two-thirds of a line from a point midway between the anterior superior iliac spine and the symphysis pubis to the adductor tubercle of the femur, with the thigh abducted and rotated outwards; the *profunda femoris* rises from it about 3 cm. below the inguinal ligament. The course of the upper part of the *popliteal artery* (fig. 1168) is indicated by a line from the lateral margin of the Semimembranosus at the junction of the middle with the lower third of the thigh to the middle of the popliteal fossa; from this point it runs vertically downwards to the level of a line through the lower part of the tibial tuberosity. The line indicating the *anterior tibial artery* (fig. 1167) is drawn from the medial side of the head of the fibula to a point midway between the malleoli; the artery begins about 3 cm. below the head of the fibula. The *dorsalis pedis artery* is represented by a line from the centre of the interval between the malleoli to the proximal end of the first intermetatarsal space.

The course of the *posterior tibial artery* (fig. 1168) can be shown by a line from the end of the popliteal artery, i.e. 2.5 cm. below the centre of the popliteal fossa, to midway between the tip of the medial malleolus and the centre of the convexity of the heel; its main branch, the *peroneal artery*, begins about 7 or 8 cm. below the level of the knee-joint and follows the line of the fibula to the back of the lateral malleolus. The *medial*

and *lateral plantar arteries* begin from the end of the posterior tibial; the medial extends to the middle of the ball of the great toe, the lateral to within a finger's breadth of the tuberosity of the fifth metatarsal bone; from this latter point the *plantar arch* crosses the foot to the proximal end of the first intermetatarsal space.

Veins.—The line of the *great saphenous vein* is from the front of the medial malleolus to the centre of the fossa ovalis (saphenous opening); the *small saphenous vein* runs from the back of the lateral malleolus to the centre of the popliteal fossa.

Nerves.—When the thigh is rotated outwards the course of the *sciatic nerve* (fig. 1168) can be indicated by a line from a point midway between the outer border of the ischial tuberosity and the posterior superior angle of the greater trochanter to the upper angle of the popliteal fossa. The continuation of this line vertically through the centre of the popliteal fossa represents the position of the *tibial nerve*, while the *common peroneal nerve* follows the line of the tendon of the Biceps femoris. The lines for the *deep peroneal nerve* and the continuation of the *tibial nerve* correspond respectively to those for the anterior and posterior tibial arteries.

INDEX

- Abdomen, 1082
 anterolateral muscles of, 456
 boundaries of, 1082
 fascia of, 456
 lymph-glands of, 724
 lymphatic vessels of, 729
 posterior muscles of, 466
 regions of, 1084
 veins of, 698
 Abdominal aorta, 631
 applied anatomy of, 632
 branches of, 632
 surface markings of, 1235
 aortic plexus, 939
 muscles, 456
 ostium of uterine tube, 1182
 portion of sympathetic system, 935
 pregnancy, 47
 ring, external, 45
 inguinal, 465
 internal, 465
 Abducent nerve, 865
 applied anatomy of, 866
 Abductor digiti quinti muscle, (hand) 508, (foot) 539
 hallucis muscle, 538
 indicis muscle, 509
 pollicis brevis muscle, 506
 longus muscle, 499
 Aberrant duct of epididymis, 1169
 Abscess, lumbar, 51
 perinephric, 1151
 pectoral, 515
 retropharyngeal, 1673
 tropical of liver, 1142
 Accessory glands of mouth, 1053
 hemiazygos vein, 693
 nerve, 881
 applied anatomy of, 882
 cerebral part of, 881
 spinal part of, 882
 obturator nerve, 913
 olivary nuclei, 708
 organs of digestion, 1046
 organs of the eye, 538
 pancreatic duct, 1132
 part of parotid gland, 1049
 plantar ligaments, 420
 processes of vertebrae, 170
 pudendal artery, 649
 sinuses of the nose, 949
 applied anatomy of, 950
 spleens, 1202
 suprarenal glands, 1206
 tectorial membrane, 1004
 thyroid glands, 1196
 volar ligaments, 387
 Acetabular fossa, 303
 ligament, transverse, 306
 notch, 303
 Acetabulum, 303
 Achromatic spindle, 2
 equator of, 2
 poles of, 2
 Acoustic meatus, external, 209, 248, 981
 applied anatomy of, 983
 development of, 108
 lymphatic vessels of, 716
 Acoustic meatus, internal, 207
 nerve, 872, 1004
 applied anatomy of, 874
 development of, 109
 nuclei of, 775, 873
 Acromegaly, 801
 Acromioclavicular articulation, 367
 applied anatomy of, 368
 movements of, 368
 surface anatomy of, 1240, 1250
 ligament, 367
 Acromion, 268
 Acrosome of spermatozoon, 44
 Actions of valves of heart, 565
 Actively growing epiphysis, 25
 Acute diaphysitis, 25
 epiphysitis, 25
 infective necrosis of bone, 25
 infective periostitis, 25
 margin of heart, 555
 poliomyelitis, anterior, 760
 Adams-Stokes' syndrome, 595, 678
 Addison's disease, 14
 Adductor brevis muscle, 520
 canal, 655
 hallucis muscle, 530
 longus muscle, 520
 magnus muscle, 521
 applied anatomy of, 522
 minimus, 521*
 pollicis muscle, 506
 tubercle, 312
 Adenoid tissue, 12
 Adipose capsule of kidney, 1146
 tissue, 9
 Aditus laryngis, 1023
 Adnitiopulum lineae albae, 460, 465
 Adrenalin, 429
 Adventitious tissue, 1059
 Affenspalte, 993*
 Afferent lymphatic vessels, 708
 nerves, 749
 vessels of kidney, 1150
 After-life, 468
 Ageusia, 118
 Aggeration, 227, 945
 Aggregated lymphatic nodules, 1113
 Air-cells, ethmoidal, 218, 949
 mastoid, 205, 957
 Air-cells or alveoli of lungs, 1042
 Air-sinuses of nose, 949
 of skull, 198*
 frontal, 218
 sphenoidal, 198, 949
 Akanthion, 200
 Ala cinerea, 768, 785
 lobuli centralis, 776
 nasi, 943
 sacralis, 173
 Ala magna, 199
 parva, 200
 of vomer, 222
 Alar cartilages of nose, 944
 folds of synovial stratum of knee-joint, 401
 lamina, 87
 ligaments, 358
 processes of ethmoidal bone, 217
 Alcock, canal of, 467
 Allantoic vessels, 597*
 Allantons, 59
 Alveolar arch, 229
 abscess, 1064
 artery, anterior superior, 590
 inferior, 589
 posterior superior, 590
 canals, 224, 226
 index, 261
 nerve, inferior, 862
 nerves, superior, 857, 858
 part of mandible, 236
 point, 260
 process of maxilla, 228
 Alveoli, formation of, for teeth, 1063
 Alveoli or air-cell of lungs, 1042
 Alveus, 819, 825
 Amacrine cells of retina, 963
 Ameloblasts, 1061
 Amnion, 61
 false, 61*
 Amniotic cavity, 50, 61
 ectoderm, 61
 fold, 61*
 Amphiarthroses, 344
 Ampulla of ductus deferens, 1168
 rectal, 1120
 of uterine tube, 1182
 of Vater, 1141
 Ampullae of lacrimae ducts, 977
 of semicircular canals, 994
 of semicircular ducts, 997
 of tabuli lactiferi, 1194
 Anaesthesia, spinal, 844
 Anal canal, 1121
 development of, 139
 lymphatic vessels of, 731
 orifice, 1122

- Anal pit, 139
region, muscles of, 471
valves, 1122
- Anaphase of karyokinesis, 2
- Anastomoses of arteries, 569
around elbow-joint, 619
around knee-joint, 663
crucial, 649, 650
- Anastomotio branch of inferior
gluteal artery, 649
vein of Labbé, 679
of Trolard, 679
- Anastomotia magna of bra-
chial artery, 619
of femoral artery, 600
- Anatomical neck of humerus,
274
- Anconæus muscle, 498
- Angina pectoris, 572
- Angioblast, 109
- Angiology, 545
- Angle, inferior lateral of
sacrum, 173
iridial or filtration, 953
- Angle of Louis, 182
- Angle of mandible, 236
- of os pubis, 302
- of rib, 187
- sacrovertebral, 171
- of sternum, 182
- subcostal, 191
- Angular artery, 584
gyrus, 809
movement, 345
vein, 673
- Angulus Ludovici, 182
- Animal, 1
- Ankle-joint, 411
applied anatomy of, 413
movements of, 413
relations of tendons and
vessels to, 412
surface anatomy of, 1256
- Annular ligament, anterior, of
ankle, 535
external, 535
internal, 535
of superior radio-ulnar
joint, 376
of wrist, anterior, 500
posterior, 502
plexus of cords, 955
- Annulus fibrosus of inter-
vertebral fibrocartilage,
350
nalis, 557
sapedis, 108
tendineus communis, 970
- Anocorcygeal body, 1121
- nerves, 927
raphe, 470, 472
- Anorchism, 1167
- Anosmia, 848
- Ansa hypoglossi, 894
lentiformis, 820, 823
subclavia (Vissersii), 932
- Anterolateral ganglionic ar-
teries, 600
muscles of abdomen, 458
- Anteromedial ganglionic ar-
teries, 599
- Anteroposterior diameter of
pelvis, 305
- Antibrachial fascia, 491
cutaneous nerve, dorsal, 905
lateral, 899
medial, 900
interosseous membrane, 377
- Antibrachial vein, median, 689
- Antibrachial muscles, dorsal,
496
volar, 491
- Anticlinal vertebra, 167*
- Antihelix, 979
- Antitragus muscle, 981
- Antitragus, 980
- Antrum cardiacum, 1081, 1098
of Highmore, 226, 950
mastoid, 986
pyloric, 1099
tympanic, 206, 986
entrance to, 986
- Anus, 1122
lymphatic vessels of, 731
- Aorta, 671
abdominal, 631
applied anatomy of, 632
branches of, 632
surface marking of, 1240
arch of, 573
applied anatomy of, 573
branches of, 574
peculiarities of, 574
peculiarities of, 573
ascending, 571
branches of, 571
bulb of, 571
descending, 627
- Aorta, thoracic, 627
applied anatomy of, 629
branches of, 629
- Aortæ, ventral, 119
dorsal, 120
primitive, 111
- Aortic arches, 112, 119
bodies, 101, 1208
hiatus, in diaphragm, 453
isthmus, 121, 573
lymph-glands, 726
orifice, 561
semilunar valves, 561
septum, 117
sinuses, 561
spindle, 573
vestibule, 561
- Aorticorenal ganglion, 938
- Ape-like hand, 907
- Apertura piriformis, 258
tympanica canaliculi chordæ,
985
- Aperture, anterior nasal, 258
inferior of pelvis, 306
superior, 305
- Apertures, posterior nasal, 258
- Apex of fibula, 322
- of heart, 553
of nose, 943
of sacrum, 175
- Aponeuroses, 425
- Aponeurosis, epicranial, 427
of obliquus externus, 458
palatine, 1073
palmar, 505
plantar, 837
suprathyoid, 440
- Aponeurotic falx, inguinal,
483
- Apoplexy, 834
ingravescent, 834
- Apparatus, digestive, 1045
development of, 128
excretory of liver, 1149
circumflex, 976
respiratory, 1016
development of, 142
urogenital, 1143
- Appendages of skin, 1011
hairs, 1012
nails, 1011
sebaceous glands, 1014
sudoriferous or sweat-
glands, 1014
of testis and epididymis,
1165
- Appendices epiploicæ, 1096,
1114, 1122
testis, 149
vesiculosæ, 1182
- Appendicular artery, 638
part of skeleton, 150
- Appendix of epididymis, 1165
of testis, 1165
of ventricle of larynx, 1023
vermiform, 1116
- Applied Anatomy of —
abdominal aorta, 632
abducent nerve, 896
accessory nerve, 882
acoustic nerve, 874
acromioclavicular joint,
368
adductor longus, 522
ankle joint, 413
anterior facial vein, 674
anterior tibial artery, 665
antrum of Highmore, 227
arch of aorta, 573
arteries, 569
ascending pharyngeal ar-
tery, 581
atrioventricular bundle,
565
auditory tube, 902
axilla, 481, 612
axillary artery, 614
fascia, 481
lymph-glands, 720
nerve, 906
vein, 690
azygos veins, 693
biceps brachii, 490
bile-duct, 1143
bone, 24
bones of foot, 340
of forearm, 286, 511
of hand, 298
of leg, 324, 541
of pelvis, 308
of skull, 202
brachial artery, 618
plexus, 906
brain, 838
branches of hypogastric or
internal iliac artery, 644
bulb of eye, 906
carotid artery common,
578
external, 579
internal, 596
carpal bones, 298
cavernous sinus, 684
cerebellum, 781
cerebrospinal fluid, 844
cervical fascia, 437
lymph-glands, 718
plexus, 895
ribs, 192
chorioid, 967
circumflex nerve, 906
clavicle, 273, 510
coccyx, 309
colon, 1127
common carotid artery,
578

Applied Anatomy of—
 common iliac artery, 643
 peroneal nerve, 928
 conjunctiva, 979
 cornea, 966
 coronary arteries, 572
 corac articulation, 398
 cubital articulation, 379
 deltoides, 486
 descending palatine artery, 590
 dorsalis pedis artery, 666
 elbow-joint, 379
 emissary veins, 687
 extensor tendons of fingers and thumb, 500
 external acoustic meatus, 983
 carotid artery, 579
 ear, 983
 iliac artery, 651
 jugular vein, 675
 maxillary artery, 584
 eyelids, 978
 facial artery, 584
 nerve, 871
 vein, anterior, 674
 fascia colli, 437
 fascia of axilla, 481
 of psoas and iliacus, 515
 femoral artery, 656
 nerve, 927
 femur, 316, 542
 fibula, 324, 544
 filtration angle of eye, 968
 fingers, 505
 flexor sheaths of fingers, 505
 foot, bones of, 330
 joints of, 422
 forearm, bones of, 286
 gall-bladder, 1142
 gluteal arteries, 651
 gums, 1047
 hæmorrhoidal venous plexus, 700
 hamstring tendons, 527
 hand, bones of, 298
 heart, 666
 hip-joint, 398
 humeral articulation, 372
 humerus, 278, 510
 hypogastric artery, 644
 hypoglossal nerve, 884
 hypophysis, 800
 iliac fascia, 515
 inferior epigastric artery, 652
 inferior vena cava, 702
 inguinal and subinguinal glands, 723
 innominate artery, 575
 intercostal arteries, 630
 nerves, 910
 internal capsule, 834
 carotid artery, 596
 ear, 1004
 iliac artery, 644
 jugular vein, 677
 mammary artery, 610
 intervertebral fibrocartilages, 351
 intestine, large, 1127
 small, 1123
 iris, 967
 ischio-rectal fossa, 472
 joints of foot, 422

Applied Anatomy of—
 kidneys, 1150
 knee-joint, 408, 527
 labyrinth of ear, 1004
 lacrimal apparatus, 979
 laryngeal nerves, 881
 larynx, 1030
 leg, bones of, 324
 lens, 968
 lienal (splenic) artery, 635
 ligamentous action of muscles, 346
 lingual artery, 582
 liver, 1142
 long thoracic nerve, 906
 lumbar plexus, 927
 lungs, 1043
 lymph-glands and lymphatic vessels, 710
 mamma, 1194
 mandible, 348
 maxillary sinus, 227
 median cubital vein, 689
 nerve, 907
 mediastinal cavity, 1036
 medulla oblongata, 772
 spinalis, 759, 838
 meninges, 844
 mesenteric arteries, 639
 lymph-glands, 728
 metacarpal bones, 298
 metatarsal bones, 340
 metatarsophalangeal joint of great toe, 420
 middle meningeal artery, 589
 motor and sensory neurons, 838
 motor and sensory tracts, 834
 muscles, 424
 of bulb of eye, 973
 of lower extremity, 542
 of upper extremity, 510
 of vertebral column, 450
 mus. tricipital nerve, 907
 nose and nasal cavities, 950
 obturator nerve, 927
 oesophagus, 1082
 ocular muscles, 973
 oculomotor nerve, 853
 olfactory nerves, 848
 optic nerve, 850
 ovary, 1181
 palate, 264
 palmar or volar arches, 627
 aponeurosis, 505
 pancreas, 1132
 parametrium, 1189
 parathyroid glands, 1198
 parotid glands, 1054
 patella, 325, 544
 pelvis, 309
 penis, 1170
 pericardium, 563
 peritoneal fossa, 1098
 phalanges, 298
 pharynx, 1079
 phrenic nerve, 895
 pign., 114
 pineal body, 798
 pituitary body, 800
 plantar arch, 669
 plantar calcaneopopliteal ligament, 477

Applied Anatomy of—
 pleura, 1034
 pons, 775
 popliteal artery, 661
 lymph-glands, 723
 portal system of veins, 706
 posterior tibial artery, 667
 pronator teres muscle, 492
 prostate, 1177
 prostatic venous plexus, 701
 proximal radio-ulnar articulation, 379
 psoas major muscle, 515
 pulmonary artery, 570
 quadriceps femoris muscle, 519
 radial artery, 622
 nerve, 907
 radiocarpal joint, 384
 radius, 287, 379, 511
 recti muscles of eye, 973
 rectum, 1127
 rectus femoris, 519
 retina, 968
 ribs, 191
 sacral plexus, 927
 salivary glands, 1054
 saphenous veins, 697
 sartorius, 518
 scalp, 427
 scapula, 271
 sciatic (inferior gluteal) artery, 651
 nerve, 927
 sclera, 967
 scrotum, 1172
 septum of tongue, 1060
 serratus anterior, 485
 sheath of psoas muscle, 515
 shoulder-joint, 372
 skull, 262
 small intestine, 1123
 spermatic plexus, 939
 sphenoidal bone, 203
 spinal ganglia, 760
 spleen, 1204
 splenic or lienal artery, 635
 sternoclavicular joint, 366
 sternocleidomastoides, 439
 sternum, 191
 stomach, 1105
 subclavian artery, 604
 superior thyroid artery, 581
 sagittal sinus, 681
 vena cava, 693
 suprarenal glands, 1207
 sympathetic nervous system, 940
 tarsal bones, 340
 joints, 418
 teeth, 1064
 temporal artery, superficial, 587
 temporomandibular joint, 348
 tendons of leg and foot, 534
 testicular veins, 703
 testis, 1167
 thoracic aorta, 629
 duct, 712
 nerves, 910
 thorax, 191
 thymus, 1206

Applied Anatomy of—
 thyroid artery, superior, 581
 gland, 1197
 tibia, 324, 544
 tongue, 1069, 1071
 palatine tonsils, 1073
 trachea, 1030
 tracheobronchial glands, 737
 triceps brachii, 401
 trigeminal nerve, 863
 trochlear nerve, 853
 tympanic cavity, 992
 ulna, 286, 511, 512
 ulnar artery, 624
 nerve, 907
 ureter, 1153
 urethra, 1162
 urinary bladder, 1159
 uterine tube, 1183
 uterus, 1189
 vagus nerve, 881
 veins in front of elbow, 689
 vena cava, inferior, 702
 superior, 693
 vertebral column, 181, 351, 358, 450
 vesiculae seminales, 1170
 volar arches, 627
 wrist-joint, 384
Aqueductus cochleæ, 208, 996
 Fallopii, 207, 986
 vestibuli, 207, 993
Aqueduct, cerebral, 793
 of Sylvius, 793
Aqueous humour, 964
Arachnoid, cerebral, 842
 spinal, 842
 structure of, 842
Arachnoidal granulations, 844
 structure of, 845
Arantii, corpus, 559, 561
Arbor vitæ of cerebellum, 778
 uterina, 1186
Arc, longitudinal, of skull, 261
Arch, alveolar, 228
 of aorta, 573
 applied anatomy of, 573
 branches of, 574
 peculiarities of, 573
 axillary, 480
 carotid, 120
 of cricoid cartilage, 1018
 glossopalatine, 1072
 hyoid, 78
 jugular venous, 675
 lumbocostal, lateral, 452
 medial, 452
 mandibular, 77
 palmar, deep, 623
 superficial, 627
 pharyngopalatine, 1072
 plantar, 668
 pubic, 306
 tendinous, of pelvic fascia, 468
 vertebral, 161
 volar, deep, 623
 superficial, 627
 zygomatic, 246
Archenteron, 80
Arches, aortic, 112, 119
 branchial, 77
 cortical, of kidney, 1147
 of fauces, 1072
 of foot, 420
 of soft palate, 1072

Arches, primitive costal, 71
 superolateral, 214, 248
 visceral, 77
Arcuate artery, 666
 fibres, external, 769
 internal, 767
 fibres of cerebellum, 781
 ligaments of diaphragm, 452
 line of ilium, 298
 nucleus, 771
 popliteal ligament, 402
 pubic ligament, 390
Arcus parieto-occipitalis, 809
Area acustica, 786
 auditory, 833
 auditory, 832
 facialis, 207
 for heat, cold and pain, 833
 for muscular sense, 833
 for sense of smell, 833
 for sense of taste, 833
 for tactile sense, 833
 motor, 831
 oval, of Flechsig, 758
 pericardial, 51
 postrema, 786
 vasculosa, 109
 vestibularis inferior, 207
 superior, 207
 visuopsychic, 832
 visuosensory, 831
Areas of Cohnheim, 31
 associational, 830
 olfactory, 79
Areola of mamma, 1193
Areolæ of bone, primary, 22
 secondary, 23
Areolar glands, 1193
 tissue, 7
 white fibres of, 7
 yellow or elastic fibres of, 8
Argyll-Robertson pupil, 838
Arm, fascia of, 488
 muscles of, 488
Arnold, canaliculus innominatus of, 200*
 nerve of, 879
Arrectores pilorum, 1014
Arteria anastomotica magna,
 of arm, 619
 of thigh, 660
 anonyma, 575
 centralis retinæ, 597, 964
 cervicalis profunda, 611
 comitans nervi ischiadici, 649
 nervi phrenici, 609
 dorsalis hallucis, 666
 pedis, 665
 femoris, 658
 intercostalis suprema, 611
 magna hallucis, 669
 mediana, 121, 625
 pancreatica magna, 635
 princeps cervicis, 585
 pollicis, 623
 profunda brachii, 619
 transversa colli, 611
 volaris indicis radialis, 623
Arterial circle of Willis, 601
 meoocordium, 551
Arteris proprie renales, 1149
 rectæ, 1150
Arteriosclerosis, 569
Artery or Arteries—
 abdominal aorta, 631
 accessory pudenda, 649
 meningeal, 589

Artery or Arteries (cont.)
 alar, of nose, 584
 alveolar, anterior superior, 590
 inferior, 589
 posterior superior, 590
 anastomoses of, 569
 anastomotio branch of inferior gluteal, 649
 anastomotica magna of brachial, 619
 of femoral, 660
 angular, 584
 anterior cerebral, 593
 chorioid, 601
 ciliary, 598
 communicating, 598
 ethmoidal, 598
 humeral circumflex, 616
 inferior cerebellar, 608
 lateral malleolar, 665
 medial malleolar, 665
 mediastinal, 609
 meningeal, 598
 spinal, 607
 superior alveolar, 590
 tibial, 604
 tympanic, 587
 anterolateral ganglionic, 601
 anteromedial ganglionic, 599
 aorta, 571
 abdominal, 631
 arch of, 573
 ascending, 571
 descending, 627
 thoracic, 627
 appendicular, 638
 applied anatomy of, 569
 arcuate, 666
 articular, of knee, 662, 663
 ascending cervical, 610
 palatine, 584
 pharyngeal, 581
 arteriosclerosis of, 569
 auditory, internal, 608
 auricular, anterior, 586
 deep, 587
 of occipital, 585
 posterior, 586
 axillary, 613
 azygos, articular of knee, 663
 of vagina, 645
 basilar, 608
 brachial, 617
 of brain, 601
 cortical system, 602
 ganglionic system, 601
 bronchial, 629, 1043
 buccinator, 590
 caecal, of ileocolic, 638
 calcaneal, lateral, 668
 medial, 668
 carotico-tympanic, 596
 carotid, common, 576
 external, 579
 internal, 594
 carpal, dorsal, 622, 625
 volar, 622, 625
 carpal network, dorsal, 623
 volar, 622
 cavernous, 596
 central, of retina, 597, 964
 cerebellar, anterior inferior, 608
 posterior inferior, 608
 superior, 608
 cerebral, anterior, 598
 middle, 599

INDEX

Artery or Arteries (cont.)

cerebral, posterior, 608
of cerebral hemorrhage, 600
cervical, ascending, 610
superficial, 611
transverse, 611
cervical profunda, 611
chorioid, anterior, 601
posterior, 608
ciliary, 597
circle of Willis, 601
circulus arteriosus major, 597
minor, 598
circumflex, anterior humeral, 616
external, 658
internal, 658
lateral femoral, 658
medial femoral, 658
posterior humeral, 616
scapular, 616
coccygeal, of inferior gluteal, 649
cochlear, 1004
colic, 632
colic, left, 638
of ileocolic, 638
middle, 638
right, 638
collateral circulation, 569
comitans nervi ischiadici, 649
nervi phrenici, 609
common carotid, 576
iliac, 642
interosseous, 625
volar digital, 627
communicating, anterior, 598
of dorsalis pedis, 666
of peroneal, 668
posterior, 600
of posterior tibial, 668
coronary, of heart, 571
of lips, 584
of stomach, 633
of corpus cavernosum penis, 647
costocervical, 611
craniastetic, 652
cricothyroid, 580
cystic, 635
deep auricular, 587
epigastric, 652
external pudendal, 657
iliac circumflex, 652
palmar arch, 623
of penis, 647
plantar, 666
temporal, 589
volar branch of ulnar, 626
dental, inferior, 589
posterior, 590
descending aorta, 627
branch of occipital, 585
palatine, 590
development of, 118
digital, volar, 627
distribution of, 569
dorsal carpal of radial, 622
of ulnar, 625
interosseous, 625
metacarpal, 623
first, 623
metatarsal, 666
plantar, 669
first, 669
nasal, 598
of penis, 647

Artery or Arteries (cont.)

segmental, 121
dorsales linguae, 582
dorsalis hallucis, 666
pedis, 665
scapulae, 616
of ductus deferens, 644
epigastric, deep or inferior, 652
superficial, 657
superior, 609
ethmoidal, 598
external carotid, 579
circumflex, 658
iliac, 651
mammary, 616
maxillary, 582
plantar, 668
pudendal, deep, 657
superficial, 657
spermatic, 652
facial, 582
transverse, 586
femoral, 653
circumflex, lateral, 658
medial, 658
fibular, 667
first dorsal metacarpal, 623
frontal, 598
of superficial temporal, 586
lingual, anterolateral, 600
anteromedial, 599
posterolateral, 608
posteromedial, 601, 608
gastric, left, 633
right, 634
short, 635
gastroduodenal, 634
gastro-epiploic, right, 634
left, 635
genicular, highest, 660
inferior, 663
middle, 663
superior, 662
gluteal, inferior, 649
superior, 650
greater palatine, 590
haemorrhoidal, inferior, 647
middle, 645
superior, 638
of head and neck, 576
helicine, 1175
hepatic, 633, 1137, 1139
highest genicular, 660
thoracic, 615
humeral circumflex, anterior, 616
posterior, 616
hyaloid, 105
hyoid, 580, 582
hypertrophy of, 569
hypogastric, 566, 568, 644
hypophyseal, 596
ileal of ileocolic, 638
of superior mesenteric, 636
ileocolic, 638
iliac, common, 642
external, 651
internal, 644
iliac circumflex, deep, 652
superficial, 657
iliolumbar, 649
inferior alveolar, 589
articular of knee, 662, 663
coronary, 584
dental, 589
epigastric, 652

Artery or Arteries (cont.)

inferior genicular, 663
gluteal, 649
haemorrhoidal, 647
labial, 584
laryngeal, 610
mesenteric, 638
pancreaticoduodenal, 636
phrenic, 641
thyroid, 610
tympanic, 581
ulnar collateral, 619
vesical, 645
infraorbital, 590
infrascapular, 616
innominate, 575
intercostal, 629
anterior ramus of, 630
posterior ramus of, 630
branches of internal mammary, 609
superior, 611
intercostalis suprema, 611
interlobular, of kidney, 1150
internal auditory, 608, 1004
carotid, 594
circumflex, 658
iliac, 644
mammary, 609
maxillary, 587
plantar, 668
pudendal, in male 646
in female 647
interosseous, common, 625
dorsal, 625
recurrent, 625
volar, 625
jejunal, 636
labial, inferior, 584
superior, 584
of labyrinth, 1004
lacrimal, 597
laryngeal, inferior, 610
superior, 580
lateral calcaneal, 668
femoral circumflex, 658
nasal, 584
palpebral, 597
plantar, 668
sacral, 649
segmental, 121
tarsal, 666
thoracic, 615
left colic, 638
gastric, 633
gastro-epiploic, 635
lienal, 635
lingual, 581
long posterior ciliary, 597
thoracic, 615
of lower extremity, 653
lumbar, 642
malleolar, anterior lateral, 665
anterior medial, 665
mammary, external, 616
internal, 609
mesenteric, 589
mastoid, 585
maxillary, external, 582
internal, 587
medial calcaneal, 668
femoral circumflex, 658
palpebral, 598
plantar, 668
tarsal, 666
malleolar, anterior lateral, 665
anterior medial, 665

INDEX

Artery or Arteries (cont.)

mediana, 121, 625
 mediastinal, from aorta, 629
 from internal mammary, 609
 medullary, 608
 meningeal, anterior, 596, 598
 accessory, 589
 anterior, of internal carotid, 596
 of ascending pharyngeal, 581
 middle, 587
 of occipital, 585
 recurrent, from lacrimal, 597
 of vertebral, 607
 mesenteric, inferior, 638
 superior, 635
 metacarpal, dorsal, 623
 volar, 623
 metatarsal, 666
 middle cerebral, 599
 colic, 638
 genicular, 663
 hemorrhoidal, 645
 meningeal, 587
 sacral, 642
 suprarenal, 639
 temporal, 596
 mode of division of, 569
 of origin of branches, 569
 musculophrenic, 609
 mylohyoid, 589
 nasal, dorsal, 598
 lateral, 584
 nerves of, 547
 nutrient, of bone, 19
 obturator, 645
 occipital, 585
 oesophageal, of inferior thyreoid, 610
 of aorta, 629
 ophthalmic, 596
 ovarian, 641
 palatine, ascending, 584
 descending, 590
 greater, 590
 smaller, 590
 palmar arch, deep, 623
 superficial, 627
 palpebral, lateral, 597
 medial, 598
 pancreatic, 635
 pancreatica magna, 635
 pancreatoduodenal, inferior, 636
 superior, 635
 of penis, deep, 647
 dorsal, 647
 perforating, of foot, 669
 of hand, 623
 of internal mammary, 609
 of thigh, 658
 pericardial, 600, 629
 pericardiacophrenic, 609
 perineal, 647
 transverse, 647
 peroneal, 667
 pharyngeal, ascending, 581
 of internal maxillary, 590
 phrenic, inferior, 641
 superior, 629
 plantar, 668
 arch, 668
 deep, 666
 lateral (external), 668
 medial (internal), 668

Artery or Arteries (cont.)

plantar metatarsal, 669
 first, 669
 pontine, 608
 popliteal, 661
 posterior auricular, 586
 cerebral, 608
 communicating, 600
 dental, 590
 ethmoidal, 598
 humeral circumflex, 616
 inferior cerebellar, 608
 meningeal, from vertebral, 607
 scapular, 611
 scrotal, 647
 spinal, 607
 superior alveolar, 590
 tibial, 666
 posterolateral ganglionic, 608
 posteromedial ganglionic, 601, 608
 princeps cervicis, 585
 pollicis, 623
 profunda brachii, 610
 cervicalis, 611
 femoris, 658
 linguae, 581, 582
 superior, 619
 proper volar digital, 627
 of pterygoid canal, 590, 596
 pudendal, accessory, 649
 deep external, 657
 internal, 646
 in female, 647
 in male, 646
 superficial external, 657
 pulmonary, 589
 pyloric, 634
 radial, 620
 recurrent, 622
 ranine, 581, 582
 recurrent of hand, 623
 interosseous, 625
 radial, 622
 tibial, anterior, 665
 posterior, 665
 ulnar, anterior, 625
 posterior, 625
 renal, 640
 right colic, 638
 gastric, 634
 gastro-epiploic, 634
 sacral, lateral, 649
 middle, 642
 scapular circumflex, 616
 posterior, 611
 transverse, 610
 sciatic, 619
 scrotal, posterior, 647
 segmental, 121
 semilunar, 596
 sheaths of, 546
 short ciliary, 598
 gastric, 635
 sigmoid, 638
 smaller palatine, 590
 spermatic, external, 652
 sphenopalatine, 590
 spinal, anterior, 607
 posterior, 607
 splenic, 635
 stapodial, 108, 119
 sternal, 609
 sternocleidomastoid, 580, 585
 striate, external, 600
 internal, 600
 structure of, 546

Artery or Arteries (cont.)

stylomastoid, 596
 subclavian, 602
 subcostal, 630
 sublingual, 582
 submental, 584
 subscapular, 616
 superficial cervical, 611
 epigastric, 657
 external pudendal, 657
 ilio circumflex, 657
 palmar arch, 627
 temporal, 586
 volar, 623
 volar arch, 627
 superior articular of knee, 662
 cerebellar, 608
 epigastric, 609
 genicular, 602
 gluteal, 650
 hemorrhoidal, 638
 intercostal, 611
 labial, 584
 laryngeal, 580
 mesenteric, 635
 pancreaticoduodenal, 635
 phrenic, 629
 profunda, 619
 thoracic, 615
 thyreoid, 580
 tympanic, 589
 ulnar collateral, 619
 vesical, 644
 supraorbital, 598
 suprarenal, inferior, 640
 middle, 639
 superior, 641
 suprascapular, 610
 sural, 662
 tarsal, lateral, 666
 medial, 666
 temporal, deep, 589
 middle, 586
 superficial, 586
 testicular, 641
 thoracic aorta, 627
 axis, 615
 highest, 615
 lateral, 615
 long, 615
 superior, 615
 thoraco-acromial, 615
 thyrocervical trunk, 610
 thyreoid axis, 610
 inferior, 610
 superior, 580
 thyroidea ima, 575
 tibial, anterior, 664
 posterior, 666
 recurrent, 665
 tonsillar, 584
 tracheal, of inferior thyreoid, 610
 transversa colli, 611
 transverse cervical, 611
 facial, 586
 scapular, 610
 of the trunk, 627
 tympanic, anterior, 587
 inferior, 581
 superior, 589
 ulnar, 623
 collateral, inferior, 619
 superior, 619
 recurrent, anterior, 625
 posterior, 625
 umbilical, in foetus, 566, 644

INDEX

Artery, Arteries (cont.)
of upper extremity, 662
urethral, 647
of urethral bulb, 647
uterine, 645
vaginal, 645
vasa aberrantia, 618
 brevia, 635
 intestini tenuis, 636
 vasorum, 647
ventral segmental, 121
vertebral, 606
vesical, inferior, 645
 superior, 644
vestibular, 1064
Vidian, 590
volar arch, deep, 623
 superficial, 627
 carpal of radial, 622
 of ulnar, 625
 deep, of ulnar, 626
 digital, common, 627
 proper, 627
 interosseous, 625
 metacarpal, 623
 superficial, 622
volaris indicis radialis, 623
zygomatoco-orbital, 586
Arterioles, 545
Arthritis deformans of hip, 309
Arthrodia 345
Articular arteries from popliteal, 662, 663
 capsules, 342
 stratum fibrosum, 342
 stratum synoviale, 342
 cartilage, 15
 end-bulbs, 1006
 fibrocartilages, 16
 lamella of bone, 342
 processes of vertebrae, 162
 tubercle of temporal bone, 203
Articular disc, 344
 of acromioclavicular joint, 367
 of distal radio-ulnar joint, 378
 of sternoclavicular joint, 366
 of temporomandibular joint, 347
Articularis genus, 510
Articulatio composita, 344
 ellipsoidea, 344
 sellaris, 344
 simplex, 344
 sphaeroides, 344
 trochoides, 344
Articulations—
 acromioclavicular, 367
 amphiarthroses, 344
 ankle, 411
 arthrodia, 344
 of atlas with epistropheus or axis, 354
 of atlas with occipital bone, 357
 of auditory ossicles, 990
 ball and socket, 344
 calcaneocuboid, 415
 carpometacarpal, 385
 classification of, 343
 condyloid, 345
 costocondral, 358
 costochondral, 363
 costotransverse, 359
 costovertebral, 358
 coxal, 393

Articulations (cont.)
of cranium with vertebral column, 357
cubital, 378
cuboidonavicular, 417
cuneocuboid, 417
cuneonavicular, 417
development of, 83
diarthroses, 344
digital, of hand, 387
 of foot, 420
elbow, 373
ellipsoid, 344
enarthrosis, 344
ginglymus, 344
gomphosis, 343
of heads of ribs, 358
hinge-joint, 344
hip, 393
humeral, 369
immovable, 343
intercarpal, 382
intercondral, 363
intercuneiform, 417
intermetacarpal, 386
intermetatarsal, 418
intertarsal, 414
knee, 309
of lower extremity, 387
of mandible, 346
of manubrium and body of sternum, 363
metacarpophalangeal, 386
metatarsophalangeal, 420
movable, 344
movements permitted in, 345
pivot, 344
pubic symphysis, 350
radiocarpal, 380
radio-ulnar, distal, 377
 proximal, 376
of ribs, 358
sacrocoxygeal symphysis, 352
sacro-iliac, 388
saddle, 344
 boulder, 369
 sphaeroid, 344
sternoclavicular, 365
sternocostal, 361
sutura, 343
symphysis, 344
 pubis, 390
synarthroses, 343
synchondrosis, 343
syndesmosis, 344
talocalcaneal, 414
talocalcaneonavicular, 415
talocrural, 411
tarsometatarsal, 418
tibiofibular, 409
 syndesmosis, 410
trochoid, 344
of upper extremity, 365
of vertebral arches, 351
of vertebral bodies, 348
of vertebral column, 348
 with cranium, 357
wrist, 380
Aryepiglottic fold, 1023
Aryepiglotticus muscle, 1026
Arytenoid cartilages, 1018
 glan, 1027
 swellings, 142
Arytenoides obliquus, 1026
transversus, 1026
Ascending aorta, 571
 cervical artery, 611

Ascending colon, 1117
 degeneration, 754
 lumbar vein, 702
 palatine artery, 584
 pharyngeal artery, 581
 applied anatomy of, 581
Association fibres of cerebral hemispheres, 828
 of cerebellum, 781
 neurons, 751
Associational areas, 833
Asterion, 261
Astragalus, 328
 ossification of, 338
Atavistic epiphyses, 24
Atlanto-occipital articulation, 357
Atlanto-occipital membrane,
 anterior, 357
 posterior, 357
Atlas, 164
 development of anterior arch of, 71
 ossification of, 177
 transverse ligament of, 355
Atresia, congenital, of pupil, 105
 of pulmonary orifice, 570
Atria of bronchi, 1042
 of heart, 555, 559
 muscular fibres of, 563
Atrial canal, 113
 systole, 565
Atrioventricular bundle, 34, 564
 applied anatomy of, 565
 groove of heart, 553
 node, 564
 orifice, left, 561
 right, 558
Atrium of heart, left, 559
 primitive, 113
 right, 555
 of middle meatus of nasal cavity, 945
Attic or epitympanic recess, 206, 984
Attraction, cone of, 47
Attraction sphere, 2
Auditory area, 833
Auditory artery, internal, 608
 ossicles, 988
 development of, 108
 pit, 106
 plate, 106
 teeth of Huschke, 1001
 tube, 988
 cartilaginous portion of, 988
 isthmus of, 988
 osseous portion of, 988
 pharyngeal ostium of, 1076
 tonsil of, 988
 torus tubarius or cushion of, 988, 1076
 veins, 1004
 vesicle, 106
Auditosensory area, 832
Auerbach's plexus, 1114
Auricle of ear, 979
 cartilage of, 980
 development of, 109
 ligaments of, 981
 lymphatic vessels of, 718
 muscles of, 981
 structure of, 980
 vessels and nerves of, 981
of heart, left, 559
 right, 555

INDEX

Auricular arteries, 585, 586
 deep, 587
 of occipital, 585
 posterior, 586
 lymph-glands, anterior, 714
 posterior, 714
 nerves, anterior, 861
 great, 892
 posterior, 870
 nerve of vagus, 879
 point, 261
 surface of ilium, 300
 of sacrum, 173
 tubercle of Darwin, 979
 vein, posterior, 674
 Auricularis anterior, 981
 posterior, 981
 superior, 981
 Auriculotemporal nerve, 861
 Auscultation of lungs, 1045
 Auscultation, triangle of, 480,
 1220
 Autonomic nerves, 741, 936
 Axes of pelvis, 306
 Axial filament of spermatozoon, 45
 Axial part of skeleton, 160
 Axilla, 612
 applied anatomy of, 612
 fascia of, 481
 Axillary arch, 480
 artery, 613
 applied anatomy of, 614
 branches of, 615
 peculiarities of, 616
 surface marking of, 1252
 fascia, 481
 nerve, 899
 applied anatomy of, 906
 lymph-glands, 719
 applied anatomy of, 720
 sheath, 613
 vein, 690
 applied anatomy of, 690
 Axis, of lens, 965
 optic, 951
 thyroid, 610
 Axis vertebræ or epistropheus,
 165
 development of, 177
 Axis-cylinder process or axon,
 35, 38
 cone of origin of, 36
 Azygos arteries of vagina, 645
 artery, articular, 663
 uvulæ, 1075
 vein, 693
 applied anatomy of, 693
 Back, deep muscles of, 444
 surface anatomy of, 1224
 surface markings of, 1226
 Ball-and-socket joint, 344
 Band of Baillarger, 821
 internal, 830
 external, 830
 of Bechterew, 831
 of Gennari, 830
 of Giacomini, 813
 iliotibial, 516
 moderator, 559
 Bar, hypochondral, 71
 Bare area of liver, 1087, 1136
 Barrel-shaped chest, 192, 271
 Bartholin, duct of, 1052
 glands of, 153, 1192
 Basal column, posterior, 752
 knobs of Engelmann, 5

Basal lamina, 87
 optic nucleus, 800
 plate of placenta, 64
 ridge or cingulum, of tooth,
 1056
 vein, 679
 Base of sacrum, 173
 of cerebral peduncle, 788
 of heart, 553
 of nose, 943
 of skull, inferior surface, 241
 superior surface, 252
 Base-line, Reld's, 1213
 Basement membranes, 12
 Basilar artery, 608
 Basilar membrane, 995, 1001
 part of occipital bone, 196
 of pons, 773
 plexus, 686
 Basileic vein, 688
 median, 687
 Basinasal length of skull, 261
 Basion, 261
 Basophil leucocytes, 29
 Basis bundle, anterior, 755
 lateral, 756
 Basis cranii externa, 241
 interna, 252
 Basivertebral veins, 694
 Basket cells of cerebellum, 781
 Bauchstiel, 59*
 Bechterew, band of, 831
 nucleus of, 775, 873
 Bed of stomach, 1100
 Bell, nerve of, 897
 Bell's paralysis, 872
 Bellini, ducts of, 1148
 Betz, giant cells of, 830
 Biceps brachii muscle, 480
 femoris muscle, 526
 Bicipital fascia, 480
 groove, 274
 ridges, 274
 Bicuspid teeth, 1057
 valve, 561
 Bifurcated ligament, 416
 calcaneocuboid part of, 416
 calcaneonavicular part of,
 416
 Bigelow, Y-shaped ligament of,
 395
 Bile-capillaries, 1139
 Bile-duct, common, 1141
 lymphatic vessels of, 732
 Bile-ducts, 1139
 stricture of, 1142
 Bipolar cells of retina, 962
 Bird's nest of cerebellum, 778
 Bismuth poisoning, 1048
 Biventer cervicis muscle, 448
 Biventral lobules of cerebellum,
 778
 Bladder, gall, 1140
 urinary, 1154
 applied anatomy of, 1159
 in child, 1156
 development of, 153
 extroversion of, 308
 female, 1157
 interior of, 1158
 ligaments of, 1157
 lymphatic vessels of, 733
 structure of, 1158
 trigone of, 1158
 vessels and nerves of, 1159
 Blandin, glands of, 1079
 Blastopore, 50
 Blind spot, 961

Blood, 20
 cells, ichthyoid, 110*
 saurid, 110
 corpuscles of, 26, 28
 origin of, 27, 109
 course of, in adult, 545
 in foetus, 566
 eosinophil corpuscles, 28
 erythroblasts, 27
 erythrocytes, 26
 islands, 109
 liquor sanguinis of, 26
 lymphocytes, 29
 microcytes, 26
 plasma, 28*
 plastids, 110
 platelets, 29
 Bochdalek, cornucopia of, 785
 Bodies, aortic, 101, 1208
 carotid, 101, 1207
 Malpighian, of kidney, 1147
 of spleen, 1203
 parathyroid, 1198
 development of, 131
 polar, 43
 restiform, 769, 779
 ultimobranchial, 132
 Body, anococegeal, 1121
 ciliary, 957
 cocegeal, 1207
 geniculate, lateral, 797
 medial, 796
 paranaphric, 1147
 perineal, 1121
 pineal, 798
 pituitary, 800
 of sternum, 182
 trapezoid, 773
 vitreous, 964
 Wolfian, 147
 Body-cavities, development of,
 143
 Body-stalk, 59, 62
 Bone, 17
 actively growing epiphysis
 of, 25
 acute diaphysitis, 25
 acute epiphysitis, 25
 acute infective necrosis, 25
 acute infective periostitis, 25
 applied anatomy of, 24
 articular lamella of, 342
 canaliculi of, 20
 cancellous tissue of, 17
 cavum medullare, 17
 cells, 20
 chemical composition of, 20
 compact substance of, 17
 diploë of, 161
 eminences and depressions
 of, 161
 Haversian canals of, 19
 systems of, 19
 lacunæ of, 19
 foramen nutritionis, 18
 lamellæ of, 19
 lymphatics of, 19
 marrow or medulla ossium
 of, 18
 medullary membrane of, 17
 minute anatomy of, 19
 nerves of, 18
 nutrient artery of, 19
 ossification of, 21
 osteoblasts, 18, 22
 osteoclasts, 23
 perforating fibres of, 20
 periosteum of, 17

INDEX

(*cont.*)

nature synostosis of, 25
spongy substance of, 17
structure and physical properties of, 17
substantia compacta of, 17
spongiosa of, 17
vessels of, 18
Bones—
astragalus, 328.
atlas, 164
axis or epistropheus, 165
calcaneus, 331
capitate, 293
carpal, 290
classes of, viz. long, flat, mixed or irregular, short, 160
clavicle or collar-bone, 271
clavicula, 271
coecyx, 176
concha, inferior nasal, 220
cranial, 193
cuboid, 335
cuneiform of carpus, 291
cuneiforms, of tarsus, 333
dermal or covering, 77
epistropheus or axis, 165
ethmoidal, 217
facial, 224
femur, 309
fibula, 322
flat, 160
of foot, 325
frontal, 211
hamate, 293
of hand, 290
hip, 298
humerus, 274
hyoid, 240
ilium, 298
incus, 989
of inferior extremity, 298
inferior nasal concha, 220
innominate, 298
interparietal, 197
irregular, 161
ischium, 301
lacrimal, 220
lesser, 221
long, 160
lunate, 291
malar, 233
malleus, 989
mandible, 235
maxilla, 224
metacarpal, 294
metatarsal, 335
of middle ear, 988
development of, 108
multangular, greater, 292
lesser, 292
nasal, 221
navicular of carpus, 290
of tarsus, 332
number of, in the body, 160
occipital, 193
os acetabuli, 304
calcis, 331
capitatum, 293
coccygis, 176
cordis, 562
coxae, 298
cuboideum, 335
cuneiforme primum, 333
secundum, 333
tertium, 334
ethmoidale, 217

Bones (*cont.*)

os frontale, 213
hamatum, 293
hyoideum, 240
ili, 298
incisivum, 229
ischii, 301
lunatum, 291
magnum, 293
multangulum majus, 292
minus, 292
naviculare manus, 290
pedis, 332
occipitale, 193
pisiforme, 291
planum of ethmoidal, 218
pubis, 302
sacrum, 171
trigonum, 332
triquetrum, 291
ossa carpi, 290
cranii, 193
faciei, 224
lacrimalia, 220
metacarpalia, 294
metatarsalia, 335
nasalia, 221
palatina, 230
parietalia, 211
suturae, 224
tarsi, 325
temporalia, 203
zygomata, 233
palatine, 230
parietal, 211
patella, 324
phalanges of foot, 337
of hand, 290
pisiform, 291
radius, 279
ribs, 145
sacrum, 171
scapula, 266
semilunar, 291
sesamoid, 340
short, 160
shoulder-blade, 266
of skull, 193
sphenoidal, 199
concha, 201
stapes, 990
sternum, 182
of superior extremity, 266
sutural, 224
talus, 328
tarsal, 325
temporal, 203
tibia, 318
trapezium, 292
trapezoid, 292
triquetral, 291
ulna, 283
unciform, 293
vertebra prominens, 166
vertebrae, cervical, 162
coccygeal, 176
lumbar, 163
thoracic, 167
sacral, 171
zygoma, 222
Wormian, 224
zygomatic, 233
Bony framework of outer nose, 943
semicircular canals, 994
Boundary layer of decidua, 64
zone of suprarenal gland, 1206.

Bowman, glands of, 948

capsule of, 1147
Brace, hypochondral, 71
Brachia of corpora quadrigemina, 792
Brachia conjunctiva of cerebellum, 778
pontis, 779
Brachial artery, 617
applied anatomy of, 618
branches of, 619
peculiarities of, 618
surface markings of, 1253
cutaneous nerve, lateral, 899
medial, 901
posterior, 905
fascia, 488
plexus, 895
applied anatomy of, 906
veins, 690
Brachialis anticus muscle, 489
Brachialis muscle, 489
Brachioradialis muscle, 496
Brachyfacial skulls, 261
Brain, 760
arteries of, 601
development of, 90
divisions of, 760
meninges of, 839
surface markings of, 1214
veins of, 679
weight of, 834
Branchial arches, 77
grooves, 77
Breadth-index of skull, 261
Breadth of skull, 261
Breasts or mammae, 1192
development of, 85
Bregma, 212, 261
Bridge of nose, 221, 943
Brim of pelvis, 305
Broad ligaments of uterus, 1937, 1186
Broca, cap of, 808
gyrus of, 808
limbic lobe of, 811
parolfactory area of, 813
Bronchi, 1027
divisions of, 1041
Bronchial arteries, 629, 1043
lymph-glands, 737
muscle, 1042
nerves, 880
veins, 694, 1043
Bronchioles, lobular, 1042
Bronchomediastinal trunks, 712, 737
Bronchopulmonary lymph-glands, 737
Bronchus, eparterial, 1041
hyparterial, 1041
intrapulmonary, 1042
left, 1028
right, 1028
Brunner's glands, 1112
Bryant's triangle, 1260
Bubonocoele, 1225
Buccae, 1046
Buccal branches of facial nerve, 870
glands, 1046
nerve, long, 860
Buccinator artery, 590
lymph-glands, 714
muscle, 431
nerve, 860
Bucconasal membrane, 89
Buccopharyngeal fascia, 436

INDEX

- Buccopharyngeal membrane**, 51
Bulb of aorta, 571
 of corpus cavernosum penis, 1173
 of eye, 951 (*see also under Eyeball*)
 olfactory, 812, 833
 optic, 102
 of posterior cornu, 817
 of vestibule, 1192
Bulbar paralysis, 772
Bulbocavernosus muscle, in female, 479
 in male, 473
Bulbo-urethral glands of Cowper, 153, 1178
Bulbs of internal jugular vein, 675, 676
Wolffian, 147*
Bulbus cordis, 113
Bulla ethmoidalis, 219, 946
Bundle, atrioventricular, 34, 564
 oval, 88, 92
 of Vicq d'Azyr, 799, 825
Burdach, tract of, 756
Burns' space, 436
Bursa, infracardiaca, 138
 omental, 1088, 1091
 development of, 136
 omenti majoris, 1092
 minoris, 1092
 pharyngeal, 1077
Bursæ beneath glutæus maximus, 522
 mucosæ, 343
 near knee-joint, 405
 near shoulder-joint, 370
 subcutaneous, 343
 subfascial, 343
 submuscular, 343
 subtendinous, 343
- Cæcal arteries**, 638
 fossæ, 1098
Cæcum, 1114
 lymphatic vessels of, 731
Calamus scriptorius, 785
Calcaneal arteries, lateral, 668
 medial, 668
 nerve, medial, 923
 sulcus, 331
 tuberosity, 332
Calcaneocuboid articulation, 415
 ligament, dorsal, 415
 plantar, 416
Calcaneofibular ligament, 412
Calcaneonavicular ligament, plantar, 416
 applied anatomy of, 417
Calcaneotibial ligament, 412
Calcaneus, 331
 ossification of, 338
Calcar avis, 807, 817
 femorale, 316
Calcarine fissure, 807
Callosal fissure, 811, 814
Calyces of kidney, 1145
Calyculi, gustatory, 942
Camper, fascia of, 457
Canaliculi of bone, 20
 dental, 1058
Canaliculus, inferior tympanic, 208, 244
 innominatus of Arnold, 200*
 mastoid, 208, 244
Canalis centralis cochleæ, 207
craniopharyngeus, 132, 203
- Canalis facialis**, 207
 reuniens of Hensen, 997, 1000
Canal or canals—
 adductor, 655
 Alcock's, 467
 alveolar, 224, 226
 anal, 1121
 development of, 139
 atrial, 113
 carotid, 208, 244
 central of medulla spinalis, 750
 of cervix of uterus, 1185
 condyloid, 196
 craniopharyngeal, 132, 203
 ethmoidal, 216, 218
 femoral, 654
 gastric, 135, 1101
 Haversian, 19
 of Huguier, 204, 985, 992
 Hunter's, 655
 hyaloid, 105, 964
 hypoglossal, 195
 incisive, 228, 236
 infraorbital, 225
 inguinal, 465
 lacrimal, 977
 mandibular, 236
 mental, 236
 neural, 53
 neurenteric, 53
 of Nuck, 152, 1187
 of Petit, 965
 pharyngeal, 243
 portal, 1139
 pterygoid, 201, 243
 pterygopalatine, 225, 231
 sacral, 175
 of Schlemm, 952
 semicircular, 994
 spiral of modiolus, 995
 vertebral, 161
Cancellous tissue of bone, 17
Canine eminence, 224
 fossa, 224
 teeth, 1056
Caninus muscle, 430
Canthi of eyelids, 974
Cap of Broca, 808
Capacity of skull, 260
Capillaries, 547
 structure of, 548
Capitate bone, 293
 ossification of, 296
Capitulum of humerus, 277
Capsula extrema, 821
 vasculosa lentis, 104
Capsule, adipose, of kidney, 1146
 of brain, external, 822
 internal, 821
 of Bowman, 1147
 of Glisson, 1094, 1138
 of lens, 965
 of Tenon, 972
Capsules, articular, 342
Caput cæcum coli, 1114
Cardiac cycle, 565
 ganglion of Wrisberg, 937
 glands of stomach, 1104
 impression on liver, 1136
 impressions on lungs, 1039
 muscular tissue, 33
 Purkinje's fibres, 34
 nerves from vagus, 880
 from sympathetic, 932, 933
 notch, 1040
- Cardiac orifice of stomach**, 1098
 plexus of nerves, 937
 valves, actions of, 565
 veins, 672
Cardinal veins, anterior, 123
 posterior, 123
Caroticooclinoid foramen, 201
 ligament, 203
Carotico tympanic artery, 596
 nerves, 931, 991
Carotid arch, 120
 artery, common, 576
 applied anatomy of, 578
 peculiarities of, 578
 surface marking of, 1223
 external, 579
 applied anatomy of, 579
 branches of, 580
 surface marking of, 1224
 internal, 594
 applied anatomy of, 596
 branches of, 596
 peculiarities of, 595
 bodies, 101, 1207
 canal, 208
 ganglion, 931
 glomera, 101
 nerve, internal, 931
 nerves from glossopharyngeal, 876
 plexus, internal, 931
 of veins, 687
 sheath, 436
 sulcus, 198
 triangles, 592
 tubercle, 164
Carpal arteries, from radial, 622
 from ulnar, 625
 bones, 290
 common characteristics of, 290
 applied anatomy of, 298
 ligament, dorsal, 503
 transverse, 500
 volar, 500
 network, dorsal, 622
 volar, 622
Carpometacarpal articulations, 385
Carpus, 290
 applied anatomy of, 298
 articulations of, 382
 ossification of, 296
 surface form of, 1246
Cartilage, 14
 alar of nose, 944
 anterior paraseptal, 77
 articular, 15
 of auricula, 980
 cells, 15
 cellular, 14
 common paraseptal, 76
 costal, 15
 cricoid, 1018
 elastic fibrocartilage, 17
 of epiglottis, 1018
 epiphysial, 22, 23
 greater alar of nose, 944
 hyaline, 14
 intrathyroid, 1017
 lateral of nose, 944
 lesser alar of nose, 944
 permanent, 14
 posterior paraseptal, 77
 of septum of nose, 943
 temporary, 14
 thyroid, 1016

INDEX

Age (cont.)
 micronasal, 223, 947
 white fibrocartilage, 16
 yellow fibrocartilage, 17
 Cartilages, arytenoid, 1018
 corniculate, 1018
 costal, 189
 cuneiform, 1018
 of larynx, 2316
 structure of, 1019
 Meckel's, 77, 237
 of nose, 943
 parachordal, 74
 prechordal, or trabeculae
 cranii, 74
 of Santorini, 1018
 of trachea, 1029
 of Wrisberg, 1018
 Cartilaginous ear capsules, 75,
 107
 framework of nose, 943
 vertebral column, 70
 Cartilago triticea, 1020
 Caruncula lacrimalis, 976
 Carunculae hymenales, 1192
 Cataract, 968
 Cauda equina, 745
 helix, 981
 Caudal fold, 55
 Caudate lobe of liver, 1135
 nucleus, 819
 process of liver, 1136
 Cavernous arteries, 596
 nerves, 940
 plexus, 931
 portion of urethra, 1162
 sinuses, 683
 applied anatomy of, 684
 nerves in, 866
 spaces of penis, 175
 Cavity or cavities—
 amniotic, 50, 61
 body, development of, 143
 glenoid, 269
 of larynx, 1022
 of lesser pelvis, 305
 mediastinal, anterior, 1035
 middle, 1036
 posterior, 1036
 superior, 1035
 medullary, 160
 of mouth, 1040
 nasal, 256, 944
 peritoneal, 1086
 pleural, 1031
 pulp, 1057
 segmentation, 49
 of septum pellucidum, 826
 sigmoid, greater, of ulna, 284
 lesser, of ulna, 285
 of radius, 282
 subarachnoid, 842
 thoracic, 550
 tympanic, 984
 of uterus, 1185
 Cavum conchae, 970
 laryngis, 1022
 Meckelli, 863
 medullare, 17
 oris, 1046
 Cell, animal, 1
 attraction sphere of, 2
 centriole of, 2
 centrosome of, 2
 definition of, 1
 division of, direct, 2
 indirect, 2
 membrane, 2

Cell, nucleus of, 2
 reproduction of, 2
 structure of, 1
 Cell-islets, interalveolar, 1192
 Cell-mass, inner, 49
 intermediate, 52, 55
 Cells, amacrine, 963
 ameloblasts, 1061
 basket, of cerebellum, 769
 of Betz, 830
 bipolar, of retina, 962
 of bone, 20
 centro-acinar, 1132
 chalice, 5
 chief or central, of fundus
 glands, 1104
 chromaffin, 1206
 clasmotocytes, 9
 of Claudius, 1003
 decidual, 64
 of Deiters, 1003
 of Dogiel, 885
 enamel, 1061
 epithelial, 4
 ethmoidal, 218, 949
 fat, 9
 germinal, 41
 germinal of medulla spinalis,
 86
 goblet, 5
 of Golgi, 36, 831
 granule, 9
 gustatory, 943
 of Hensen, 1093
 horizontal, of retina, 963
 lamellar, 9
 of liver, 1139
 luteal, 1181
 of Martinotti, 831
 mastoid, 205
 mesan-boid, 100
 mitral, 834
 nerve, 35
 olfactory, 948
 oxyntic or parietal, 1104
 pigmented, 13
 plasma, 9
 prickle, 7, 1009
 of Purkinje, 781
 of Sertoli, 1166
 somatic, 41
 of spinal ganglia, 743, 885
 splenic, 1202
 stellate, of Kupfer, 1139
 tendon, 11
 wandering, 9
 Cellular cartilage, 14
 Cellulitis, pelvic, 1190
 Cement or crusta petrosa of
 teeth, 1059
 formation of, 1062
 Central artery of retina, 597
 canal of medulla spinalis,
 750
 or chief cells of fundus glands,
 1104
 grey stratum of cerebral
 aqueduct, 793
 gyrus, anterior, 808
 posterior, 809
 ligament of medulla spinalis,
 846
 nervous system, 740
 part of lateral ventricle, 816
 sulcus, 806
 tendinous point of perineum,
 473
 tendon of diaphragm, 453

Centres, higher or cortical
 visual, 802, 850
 lower visual, 802, 850
 of ossification, 22
 Centrifugal nerve-fibres, 742
 Centriole, 2
 Centripetal nerve-fibres, 742
 Centro-acinar cells, 1132
 Centrosome, 2
 Centrum ovale majus, 814
 minus, 813
 Cephalic flexure, ventral, 90
 fold, 55
 index, 261
 portion of sympathetic sys-
 tem, 931
 vein, 687
 accessory, 688
 Cerebellar artery, anterior in-
 ferior, 608
 posterior inferior, 607
 superior, 608
 hemispheres, 775
 notches, 775
 peduncles, 778, 779
 tract, direct, 756
 veins, 680
 Cerebello-olivary fasciculus, 769
 Cerebellospinal tract of Löwen-
 thal, 755
 Cerebellum, 775
 applied anatomy of, 783
 brachia conjunctiva of, 778
 pontis of, 779
 development of, 93
 fibrae propriae of, 781
 grey substance of, 781
 lobes of, 775
 nucleus dentatus of, 781
 peduncles of, 778, 779
 restiform bodies, 779
 structure of, 778
 inferior surface of, 777
 superior surface of, 776
 vermis of, 775
 white substance of, 778
 Cerebral aqueduct, 793
 arteries, anterior, 598
 middle, 599
 posterior, 608
 cortex, laminae of, 820
 nerve-cells of, 829
 nerve-fibres of, 829
 special types of, 831
 structure of, 829
 dura mater, 839
 fissures and sulci—
 calcarine, 807
 callosal, 811
 central, 806
 cingulate, 807
 circular, 807, 811
 collateral, 807
 fimbriodentate, 813
 frontal, 808
 hippocampi, 812
 interlobar, 806
 intraparietal of Turner,
 806
 lateral, 806
 longitudinal, 805
 lunate, 809
 medial frontal of Eber-
 staller, 808
 occipital, lateral, 809
 transverse, 809
 olfactory, 808
 paramedial, 808

INDEX

- Cerebral fissures and sulci (cont.)**
 parieto-occipital, 807
 parolfactory, anterior, 813
 postcentral, 809
 precentral, 808
 of Rolando, 806
 subparietal, 809
 of Sylvius, 806
 temporal, 810
 ventricle, fourth, 783
 lateral, 815
 third, 802
- Cerebral hemispheres, 804**
 association fibres of, 828
 borders of, 805
 commissural fibres of, 828
 development of, 96
 fissures of, 806
 gray substance of, 829
 gyri of, 808
 interior of, 813
 lobes of, 807
 poles of, 805
 projection fibres of, 828
 structure of, 827
 sulci of, 806
 surfaces of, 805
 transverse fibres of, 828
 white substance of, 827
- nerves, 846**
 development of, 100
 abducent, 865
 accessory, 881
 acoustic, 872
 facial, 867
 glossopharyngeal, 875
 hypoglossal, 883
 oculomotor, 851
 olfactory, 847
 optic, 848
 trigeminal, 853
 trochlear, 852
 vagus, 877
 peduncles, 787
 structure of, 787
 veins, external, 679
 internal, 680
 vesicles, 53, 90
- Cerebro-olivary fasciculus, 769**
Cerebrospinal fasciculus, anterior, 754
 lateral, 755
 fibres of internal capsule, 822
 uncrossed, 755
 fluid, 844
 applied anatomy of, 844
 nerves, structure of, 741
 nervous system, 740
- Ceruminous glands, 983**
Cervical artery, ascending, 610
 superficial, 611
 transverse, 611
 branch of facial nerve, 871
 curve of vertebral column, 179
 enlargement of medulla spinalis, 746
 fascia, 435
 applied anatomy of, 437
 flexure of embryonic brain, 91
 ganglion, inferior, 933
 middle, 932
 superior, 932
 lymph-glands, anterior, 715
 deep, 715
 superficial, 715
 applied anatomy of, 718
- Cervical muscles, superficial and lateral, 437**
 nerve, cutaneous or transverse, 893
 nerves, anterior divisions of, 891
 posterior divisions of, 887
 plexus, 891
 applied anatomy of, 895
 deep branches of, 894
 superficial branches of, 891
 posterior, 888
 portion of sympathetic system, 932
 irritation of, 940
 paralysis of, 941
 ribs, 166, 192
 applied anatomy of, 191
 vein, deep, 678
 vertebrae, 162
- Cervicalis ascendens muscle, 447**
 profunda artery, 611
 Cervix of uterus, 1185
 Chalice or goblet cells, 5
 Chambers of the eye, 958
 Changes in vascular system at birth, 568
 Chassaignac's tubercle, 164
 Check ligaments, 358
 of eye, 972
 Cheeks, 1046
 mucous membrane of, 1046
 Chemical composition of bone, 20
 of teeth, 1059
 Chest or thorax, 190
 Chiasma, optic, 802, 849
 Chief or central cells of fundus glands, 1104
 Choanae, 243, 258, 945
 permanent, 81
 primitive, 80
 Choked-disc, 850
 Cholecystotomy, 1142
 Chondrin, 17
 Chondrification of the skull, 74
 Chondrocranium, 74
 Chondroglossus muscle, 1068
 Chondromucoid, 17
 Chorda tympani nerve, 870, 992
 Chordæ tendinae of left ventricle, 561
 of right ventricle, 559
 Willisii, 680
 Chordal part of base of skull, 74
 Chorioid coat of eyeball, 955
 applied anatomy of, 967
 structure of, 955
 plexuses of fourth ventricle, 785
 of lateral ventricle, 826
 of third ventricle, 802
 vein, 680
 Chorioidial artery, anterior, 601
 posterior, 608
 fissure of brain, 837
 of optic cup, 102
 Chorion, 65
 frondosum, 66
 laeve, 66
 Chorionic villi, 66
 Chromaffin cells, 1206
 organs, 101
 Chromatin, 2
- Chromatolysis, 38, 754***
Chromosomes, 2
 daughter, 2
 number of, in man, 2
 Chyle, 707
 Chyliferous vessels, 707
 Cilia or eyelashes, 974
 Ciliaris muscle, 957
 Ciliary arteries, 597
 body, 957
 ganglion, 856
 glands, 974
 nerves, long, 855
 short, 856
 processes, 957
 Ciliated epithelium, 5
 Ciliospinal reflex, 838
 Cingulate gyrus, 811
 sulcus, 807
 Cingulum of cerebral hemisphere, 828
 of tooth, 1056
 Circle, arterial, of Willis, 601
 Circular folds of small intestine, 1110
 sinus, 686
 sulcus, 807
 Circulating fluids, 26
 blood, 26
 lymph, 29
 Circulation of blood in adult, 545
 in foetus, 566
 vitelline, 57, 112
 Circulus major of iris, 597, 960
 minor, 596, 960
 venosus of mamma, 1194
 Circumduction, movement of, 345
 Circumference of skull, 261
 Circumferential fibrocartilage, 16
 lamellæ, 19
 Circumflex artery, anterior
 humeral, 616
 posterior, 616
 lateral femoral, 658
 medial, 658
 external, 658
 internal, 658
 scapular, 616
 nerve, 899
 applied anatomy of, 906
 Cisterna basalis, 843
 cerebellomedullaris, 843
 chiasmatis, 843
 chylii, 711
 fossæ cerebri lateralis, 843
 interpeduncularis, 843
 magna, 843
 pontis, 843
 vena magna cerebri, 843
 Cisternæ, subarachnoid, 843
 Clarke's column, 751, 756
 Clasmatoocytes, 9
 Classification of bones, 160
 of joints, 343
 of skulls, 262
 Claudius, cells of, 1003
 Claustrum, 821
 Clava, 764
 Clavicle, 271
 applied anatomy of, 273
 ossification of, 273
 peculiarities in sexæ, 273
 structure of, 273
 surface anatomy of, 1244

INDEX

a, 271
 palate, 264
 pudendal, 1191
 Clinging fibres of cerebellum, 782.
 Clinoid processes, anterior, 201, 252
 middle, 197, 254
 posterior, 138, 254
 Clitoris, 1192
 dorsal nerve of, 926
 frenulum of, 1192
 glands of, 1192
 prepuce of, 1192
 Clivus monticuli of cerebellum, 777
 Cloaca, ectodermal, 139
 entodermal, 139
 pelvic portion of, 153
 phallic portion of, 153
 vesico-urethral portion of, 153
 Cloacal membrane, 51, 139
 duct, 139
 tubercle, 154
 Cloquet, lymph-gland of, 723
 Closed part of medulla oblongata, 761
 Closing membranes, 77
 Club-foot, or talipes, 534
 Coccygeal arteries, 649
 body, 1207
 cornua, 176
 nerve, anterior division of, 917
 posterior division of, 890
 plexus, 927
 Coccygeus muscle, 471
 Coccygodynia, 309
 Coccyx, 176
 cornua of, 176
 displacement of, 309
 ossification of, 179
 Cochlea, 994
 aqueduct of, 208, 244, 996
 cupula, of 995
 hamulus laminae spiralis of, 996
 helicotremia of, 995, 996
 modiolus of, 995
 osseous spiral lamina of, 935
 scala of, 996
 secondary spiral lamina of, 996
 spiral canal of, 995
 vessels of, 1004
 Cochlear artery, 1004
 nerve, 873, 1004
 nuclei, 775, 873
 Cochleariform process, 209, 988
 Coeliac artery, 632
 branches of vagus nerve, 881
 ganglia, 938
 plexus, 937
 Coelom, 50, 53, 143
 Cog-tooth or spur of malleus, 980
 Cohnheim, areas of, 31
 Colic artery, left, 638
 middle, 638
 right, 638
 arteries of ileocolic, 638
 flexure, left, 1114, 1118
 right, 1114, 1117
 impression, 1136
 valve, 1115
 Collagen, 11
 Collar-bone, 271

Collateral circulation, 569
 after ligation of—
 abdominal aorta, 632
 axillary artery, 615
 brachial artery, 619
 carotid artery, common, 579
 external, 580
 femoral artery, 657
 iliac artery, common, 643
 external, 652
 internal or hypogastric, 644
 innominate artery, 575
 subclavian artery, 606
 eminence, 819
 fissure, 807
 Collaterals of nerve-fibres, 38
 Collecting tubules of kidney, 1148
 Colles, fascia of, 458, 473
 Colles's fracture, 287
 Colliculi inferior, 792
 superior, 792
 Colliculus of arytenoid cartilage, 1018
 facialis, 775, 785
 seminalis, 1161
 Coloboma, congenital, 102, 967
 Colon, 1117
 applied anatomy of, 1127
 ascending, 1117
 descending, 1118
 iliac, 1119*
 left or splenic flexure of, 1114, 1118
 right or hepatic flexure of, 1114, 1117
 lymphatic vessels of, 731
 sigmoid or pelvic, 1119
 structure of, 1122
 transverse, 1118
 vessels and nerves of, 1123
 Colostomy, 1127
 Colostrum corpuscles, 1194
 Coloured or red corpuscles, 26
 Colourless corpuscles, 28
 Columella, of nose, 80
 Column, anterior, of medulla spinalis, 749
 lateral, 749
 posterior, 749
 of Clarke, 751, 756
 vertebral, 161, 179
 cartilaginous, 70
 development of, 69
 membranous, 69
 Columna nasi, 943
 vertebralis, 161
 Columnar epithelium, 4
 Columns, of fornix, 824
 rectal, of Morgagni, 1122
 renal, 1147
 of vagina, 1190
 Comes nervi phrenici, 609
 Comitans nervi phrenici, 649
 Comma-shaped fasciculus, 758
 Communicated fibres of cerebral hemispheres, 828
 of cerebellum, 781
 crossed, 751
 Commissure, anterior, of brain, 98, 807
 middle or grey, 794
 posterior, 95, 798
 habenular, 797
 hippocampal, 824
 of Gudden, 802, 850

Commissure of medulla spinalis, anterior white, 747
 grey, 750
 optic, 849
 Commissures of brain, development of, 98
 of labia majora, 1191
 palpebral, 974
 Common bile-duct, 1141
 lymphatics of, 732
 carotid artery, 576
 applied anatomy of, 578
 peculiarities of, 578
 dental germ, 1060
 iliac arteries, 642
 lymph-glands, 725
 veins, 701
 integument, 1008
 interosseous artery, 625
 mesentery, posterior, 135
 peroneal nerve, 924
 Communicans fibularis nerve, 924
 tibialis nerve, 923
 Communicantes cervicales nerves, 894
 Communicating artery, anterior, 598
 posterior, 600
 from dorsalis pedis, 666
 of peroneal, 668
 of posterior tibial, 668
 Compact substance of bone, 17
 Comparison of bones of hand and foot, 339
 Complexus muscle, 448
 Compound palmar ganglion, 508
 Compressor naris muscle, 429
 Concentric corpuscles of Hassall, 1200
 Concha of auricula, 979
 cartilaginea, 979
 cymba conchae, 979
 inferior nasal, 220
 ossification of, 220
 middle nasal, 219
 superior nasal, 219
 Conchae nasales inferiores, 220
 sphenoidal, 201
 Condyle of mandible, 237
 Condyles of femur, 313
 occipital, 195
 of tibia, 318
 Condylod articulation, 345
 canal, 196
 foramen, anterior, 195
 fossa, 196
 process of mandible, 237
 vein, 687
 Cone of attraction, 47
 Cone of origin of axon, 36
 Cone-bipolars of retina, 963
 Cone-granules of retina, 963
 Cones of retina, 963
 Confluence of the sinuses, 104
 683
 Congenital fissures in cranium, 224
 hernia, 1126
 complete, 1126
 incomplete, 1126
 hydrocele, 1168
 Congenital coloboma, 102
 atresia of pupil, 105
 hypertrophic stenosis of pylorus, 1105
 Coni vasculosi, 1167

INDEX

- Conical stump, 25
 Conjoined tendon of obliquus internus and transversalis muscles, 463
 Conjugate diameter of pelvis, 305
 Conjunctiva, 976
 applied anatomy of, 979
 Connecting fibrocartilages, 16
 piece or body of spermatozoön, 44
 Connective tissue, extra-peritoneal, 466
 subperitoneal, 466
 Connective tissues, proper, 7
 adipose, 9
 areolar, 7
 development of, 14
 lymphatics of, 12
 lymphoid or adenoid, 12
 mucous, 12
 nerves of, 13
 retiform or reticular, 12
 vessels of, 12
 white fibrous, 10
 yellow elastic, 11
 Conoid ligament, 368
 tubercle, 271
 Constriction, duodenopyloric, 1099
 Constrictor pharyngis inferior, 1078
 medius, 1078
 superior, 1078
 urethræ muscle, 476
 Contraction of hamstring tendons, 527
 Conus arteriosus, 558
 tendon of, 558
 medullaris, 745
 elasticus of larynx, 1021
 Contour lines of Owen, 1059
 Convoluted tubules of kidney, 1147
 Convolutions of brain (see under 'Gyrus')
 Cooper, ligament of, 460
 ligamenta suspensoria of, 481
 Copula, 130
 Cor, 553
 Coraco-acromial ligament, 368
 Coracobrachialis muscle, 488
 Coracoclavicular fascia, 483
 ligament, 367
 Coracohumeral ligament, 370
 Coracoid process, 269
 tuberosity, 271
 Cord, genital, 149
 nephrogenic, 52
 spermatic, 1171
 spinal, 745
 umbilical, 62
 Corium or cutis vera, 1010
 Cornea, 952
 applied anatomy of, 966
 structure of, 953
 Corneal corpuscles, 954
 epithelium, 954
 spaces, 954
 Corniculate cartilages, 1018
 Cornua ooccygeal, 176
 of fossa ovalis, 517
 of hyoid bone, 240, 241
 of lateral ventricles, 817 318
 of medulla spinalis, 749
 nasal, 172
 of thyroid cartilage, 1017
 Cornucommissural fasciculus, 757
 Cornucopia of Bochdalek, 785
 Corona glandis, 1174
 radiata of brain, 822
 of ovum, 43
 Coronal suture, 241, 245
 Coronary arteries, of heart, 571
 applied anatomy of, 572
 peculiarities of, 572
 of face, 584
 artery of stomach, 633
 ligament of liver, 1086, 1087
 ligaments of knee, 405
 plexuses, 937
 sinus, 671
 opening of, 556
 valve of, 557, 671
 sulcus of heart, 553
 vein of stomach, 706
 Coronoid fossa, 277
 process of mandible, 237
 of ulna, 284
 Corpora cavernosa clitoridis, 1192
 penis, 1173
 artery of, 647
 bulbs of, 1173
 crura of, 1173
 mamillaria, 799
 quadrigemina, 791
 brachia of, 792
 structure of, 792
 Corpus Arantii, 559, 561
 callosum, 814
 development of, 98
 genu of, 814
 rostrum of, 814
 splenium of, 815
 cavernosum urethræ, 1173
 Highmori, 1165
 luteum, 1181
 spongiosum, 1173
 striatum, 97, 819
 subthalamium, 799
 Corpuscles, coloured, 26
 origin of, 27
 colostrum, 1194
 colourless, 28
 concentric, of Hassall, 1200
 corneal, 954
 eosinophil, 28
 genital, 1006
 of Golgi and Mazzoni, 1007
 of Grandry, 1006
 of Hassall, 1200
 of Herbat, 1007
 hyaline, 28
 lymphocyte, 29
 oxyphil or neutrophil, 28
 Pacinian, 1006
 polymorphonuclear, 28
 of Ruffini, 1007
 of Wagner and Meissner, 1007
 Corrugator muscle, 429
 cutis ani muscle, 472
 Cortex of cerebellum, 781
 of cerebrum, 829
 of hair, 1014
 Corti, ganglion of, 1004
 pillars or rods of, 1002
 spiral organ of, 1001
 tunnel of, 1001
 Cortical arches of kidney, 1147
 arterial system of brain, 602
 portion of suprarenal gland, 1206
 Cortical substance of kidney, 1147
 of lens, 965
 visual centre, 850
 Corticostriate fibres, 820
 Corticothalamic fibres, 796
 Costæ spurie, 186
 vera, 185
 Costal cartilages, 189
 arches, primitive, 71
 cartilage, 15
 groove, 187
 pleura, 1032
 process of a cervical vertebra, 164
 tuberosity, 272
 Costocervical artery, 611
 Costochondral articulations, 363
 Costoclavicular ligament, 366
 Costocoracoid ligament, 483
 membrane, 483
 Costomediastinal sinus, 1034
 Costotransverse articulations, 359
 ligament, anterior, 360
 interosseous, 360
 posterior, 360
 Costovertebral articulations, 358
 Costoxiphoid ligaments, 362
 Cotyledons of placenta, 65, 48
 Cotyloid ligament, 396
 Covering bones, 77
 Coverings of direct inguinal hernia, 1126
 of femoral hernia, 1127
 of oblique inguinal hernia, 1125
 of ovum, 42
 Cowper's glands, 153, 1178
 Coxal articulation, 393
 applied anatomy of, 398
 movements of, 397
 muscles in relation to, 396
 Cranial bones, 193
 fossa, anterior, 252
 middle, 252
 fossa, posterior, 254
 Craniology, 260
 Craniopharyngeal canal, 132
 Craniotabes, 224
 Craniovertebral articulations, 357
 Cranium, 193
 bones of, 193
 breadth of, 261
 congenital fissures in, 224
 development of, 72
 height of, 261
 horizontal circumference of, 261
 length of, 261
 longitudinal arc of, 261
 Cremaster muscle, 461
 Cremasteric artery, 652
 fascia, 462, 1171
 Crescents of Gianuzzi, 1053
 Crest or crests—
 anterior of tibia, 320
 frontal, 215
 of greater and lesser tubercles of humerus, 274
 of ilium, 300
 incisor, 229
 infratemporal, 200, 246
 inguinal, 151
 internal occipital, 194, 255

INDEX

(cont.)
 chanteric, 312
 rimal, anterior, 227
 posterior, 220
 lateral sacral, 172
 medial, 172
 nasal, 229
 neural, 53, 88
 obturator, 303
 pubic, 302
 sacral articular, 172
 sphenoidal, 178
 of spine of scapula, 268
 supramastoid, 203
 tympanic, 210*
 urethral in female, 1163
 in male, 1161
 Cricket-thigh, 519
 Cricothyroideoid ligament, posterior, 1021
 Cricothyroideoid lateral muscle, 1025
 posterior muscle, 1025
 Cricoid cartilage, 1018
 Cricothyroid artery, 581
 ligament, middle, 1021
 membrane, 1021
 Cricothyroideus muscle, 1025
 Cricotracheal ligament, 1020
 Crista ampullaris, 998
 arcuate of arytenoid cartilage, 1018
 basilaris, 1000
 capituli, 186
 colli costae, 187
 conchalis, 226, 231
 ethmoidalis, 227, 231
 galli, 217
 terminalis of right atrium, 114, 555
 transversa, 207
 vestibuli, 993
 Crossed commissural fibres, 751
 pyramidal tract, 755
 Crosses of Ranvier, 39
 Crown of a tooth, 1058
 Crucial anastomosis, 649, 658
 Cruciate crural ligament, 535
 eminence of occipital bone, 194
 ligaments of knee, 403
 Crura cerebri, 787
 of diaphragm, 452
 of fornix, 825
 of incus, 989
 of penis, 1173
 of stapes, 990
 of subcutaneous inguinal ring, 458
 Crural branch of genitocrural nerve, 913
 interosseous membrane, 409
 ligament, cruciate, 535
 transverse, 535
 nerve, anterior, 916
 septum, 654
 Crureus muscle, 519
 Crus commune of semicircular canals, 994
 helialis, 979
 Crusta or pes of cerebral peduncle, 788
 petrosal, or cement of teeth, 1059
 formation of, 1062
 Crutch-palsy 486, 906
 Cruveilhier, glenoid ligaments of, 397, 430

Cryptorchismus, 152
 Crypts of Lieberkühn, 1112
 Crystalline lens, 965 (see also under Lens)
 Orbital articulation, 373
 applied anatomy of, 379
 movements of, 378
 vessels and nerves of, 376
 fossa, 617
 vein, median, 688
 Cuboid bone, 335
 ossification of, 338
 Cuboideonavicular articulation, 417
 Culmen monticuli of cerebellum, 777
 Cuneate nucleus, 764
 tubercle, 764
 Cuneiform bone of carpus, 291
 ossification of, 296
 first, of tarsus, 333
 ossification of, 338
 second, 333
 ossification of, 338
 third, 334
 ossification of, 338
 cartilages, 1018
 tubercle, 1023
 Cunoocuboid articulation, 417
 Cuneonavicular articulation, 417
 Cuneus, 809
 Cup, optic, 102
 Cupula of cochlea, 995
 of pleura, 1033
 Curvature, lateral of vertebral column, 179
 Curvatures of stomach, 1099
 Curved lines of ilium, 298, 299
 Curves of the vertebral column, 179
 Cushion or torus of auditory tube, 988, 1076
 or tubercle of epiglottis, 1019
 Cushions, endocardial, 115
 Cusps, 1056
 Cusps of bicuspid valve, 561
 of tricuspid valve, 558
 Cutaneous branches of musculospiral nerve, 905
 cervical nerve, 893
 Cutaneous nerve, dorsal anti-brachial, 905
 external, of thigh, 913
 intermediate, of thigh, 916
 intermediate dorsal, of foot, 925
 internal, of forearm, 900
 lateral anti-brachial, 899
 brachial, 899
 dorsal, of foot, 923
 femoral, 913
 lesser internal, of forearm, 901
 medial anti-brachial, 900
 brachial, 901
 dorsal, of foot, 925
 sural, 923
 of thigh, 916
 perforating, 926
 posterior brachial, 905
 femoral, 920
 Cuticle, 1008
 Cuticula dentis, 1062
 Cutis plate, 69
 vera or corium, 1010
 Cuvier, ducts of, 113, 123
 Cycles, cardiac, 585

Cylinders, hepatic, 139
 Cylindrical epithelium, 4
 Cymba conchae, 879
 Cystic artery, 635
 duct, 1141
 lymph-gland, 727
 vein, 706
 Cystotomy, suprapubic, 1160
 Cysts, dental, 265
 dentigerous, 265
 Cyton, 36
 Cytoplasm, 41
 Cytotrophoblast, 50, 65
 Dacryon, 261
 Dangerous area of eye, 968
 Dartos tunic, 457, 1171
 Darwin, auricular tubercle of, 979
 Daughter chromosomes, 2
 Decidua, 64
 basalis, 65
 capsularis, 66
 limiting or boundary layer of, 64
 parietalis or vera, 65
 placentalis, 65
 stratum compactum of, 64
 spongiosum of, 64
 Decidual cells, 64
 Deciduous teeth, 1057
 development of, 1060
 Decussation of lemniscus, 767
 of Meynert, 792
 partial of optic nerves, 849
 pyramidal, 762
 sensory, 767
 Deep artery of penis, 647
 auricular artery, 587
 branch of radial nerve, 906
 cervical fascia, 435
 lymph-glands, 715
 vein, 678
 epigastric artery, 652
 external pudendal artery, 657
 fascia of forearm, 491
 iliac circumflex vein, 699
 muscles of back, 444
 palmar arch, 623
 peroneal nerve, 925
 petrosal nerve, 858, 931
 plantar artery, 666
 temporal arteries, 589
 nerves, 860
 transverse fascia of leg, 528, 531
 volar arch, 623
 branch of ulnar artery, 926
 Deformities of skull, 264
 Degeneration, Wallerian, 40, 754
 Deglutition, 1079
 Deiters, cells of, 1003
 nucleus of, 775, 878
 Deltoid ligament, 411
 tubercle, 271
 tuberosity, 276
 Deltoid muscle, 485
 applied anatomy of, 486
 Deltoidopectoral triangle, 483
 lymph-glands, 719
 Demilunes of Heidenhain, 1053
 Dendrons of nerve-cells, 36
 Dens of epistropheus, 185
 serotinus, 1057
 Dental artery, inferior, 589
 posterior, 590

INDEX

Dental canaliculi, 1058
 cysts, 265
 formula, 1054
 furrow, 1060
 germ, common, 1060
 special, 1060
 index, 262
 length, 262
 lamina, 1060
 matrix, 1059
 nerve, inferior, 882
 pulp, 1057
 sac, 1061
 Dentate gyrus, 813, 833
 nucleus of cerebellum, 782
 Dentes, 1054
 Dentigerous cysts, 265
 Dentina canaliculi, 1058
 fibres, 1059
 matrix, 1058
 sheath of Neumann, 1058
 Dentine, 1058
 formation of, 1062
 secondary or adventitious,
 1059
 Depressions for arachnoidal
 granulations, 211
 Depressor anguli oris, 430
 septi, 429
 Dermal bones, 77
 Dermic coat of hair follicle,
 1013
 Descendens cervicalis nerve,
 894
 Descending aorta, 627
 colon, 1118
 comma-shaped fasciculus,
 758
 degeneration, 754
 palatine artery, 590
 process of lacrimal bone, 221
 ramus of hypoglossal nerve,
 884
 Descent of testis, 151
 of ovaries, 152
 Detrusor urinae, 1159
 Deuteroplasm, 2, 41
 Development of—
 acoustic meatus, external,
 108
 nerve, 109
 adipose tissue, 10
 allantois, 59
 amnion, 61
 anal canal and rectum, 139
 arteries, 118
 articulations, 83
 auricula or pinna, 109
 body cavities, 143
 brain, 90
 branchial or visceral arches,
 77
 cerebellum, 92
 cerebral hemispheres, 96
 nerves, 100
 chorion, 65
 chromaffin organs, 101
 commissures of brain, 98
 connective tissues, 14
 corpus callosum, 98
 stratum, 97
 deciduous teeth, 1060
 diencephalon, 94
 digestive apparatus, 128
 ear, 106
 external organs of genera-
 tion, 153
 eye, 102

Development of—
 face, 79
 fissures and sulci of cere-
 brum, 98
 fetal membranes and pla-
 centa, 59
 fore-brain, 93
 generative and urinary
 organs, 145
 genital glands, 149
 glands of skin, 85
 hairs, 85
 heart, 111, 113
 hind-brain, 91
 hypophysis cerebri, 132
 inferior vena cava, 124
 joints, 83
 kidney, 152
 lacrimal apparatus, 106
 laminae of cerebral cortex,
 831
 limbs, 82
 liver, 139
 lungs, 142
 lymphatic system, 127
 mammary gland, 85
 medulla oblongata, 91
 spinalis, 86
 membranous labyrinth, 106
 mesencephalon, 92
 mesonephros, 146
 metanephros, 152
 mid-brain, 92
 milk-ridge, 85
 mouth, 129
 Müllerian duct, 149
 muscle-fibres, 34
 muscles, 84
 nails, 85
 nasal capsule, 76
 neopallium, 97
 nervous system, 85
 neural groove and tube, 53
 nose, 79
 notochord, 54
 olfactory nerves, 102
 ovary, 150
 palate, 80
 palatine tonsils, 131
 pancreas, 141
 parathyroid bodies, 131
 parietes, 69
 permanent kidney, 152
 teeth, 1063
 pharyngeal pouches, 77
 pinna or auricula, 109
 placenta, 66
 pons, 92
 primary nail-fields, 85
 primitive segments, 55
 streak, 50
 pronephric duct, 146
 pronephros, 146
 prosencephalon, 93
 prostate, 153
 rectum and anal canal, 139
 respiratory organs, 142
 retina, 102
 rhinencephalon, 96
 rhombencephalon or hind-
 brain, 91
 ribs, 71
 salivary glands, 130
 sebaceous glands, 85
 sense organs, 85
 sinus venosus, 113
 skeleton, 69
 skin and its appendages, 84

Development of—
 skull, 72
 spinal nerves, 88
 spleen, 141
 sternum, 72
 sudoriferous glands, 85
 sulci and fissures of cere-
 brum, 98
 suprarenal glands, 101
 sweat-glands, 85
 sympathetic system, 100
 teeth, 1060
 telencephalon, 95
 testis, 151
 thymus, 131
 thyroid gland, 131
 tongue, 130
 tympanic cavity, 107
 ossicles, 108
 umbilical cord, 62
 urethra, 154
 urinary bladder, 153
 urinary and generative
 organs, 145
 valves of heart, 118
 vascular system, 109
 veins, 122
 vertebral column, 69
 visceral or branchial arches,
 77
 Wolffian duct, 146
 yolk-sac, 57
 Diameters of pelvis, 305, 306
 Diaphragm, 452
 actions of, 454
 central tendon of, 453
 crura of, 452
 lymphatic vessels of, 738
 openings in, 453
 relations of, 454
 pelvic, 467, 1084
 urogenital, 475
 Diaphragma sellae, 800, 841
 Diaphragmatic lymph-glands,
 736
 part of pelvic fascia, 468
 pleura, 1033
 surface of heart, 554
 Diaphysis, 24, 160
 Diaphysitis, acute, 25
 Diarthroses, 344
 Diaster, 3
 Diencephalon, 94, 793
 Differentiation of cells, 41
 Digestive fossa of mandible, 235
 of temporal bone, 205
 nerve, from facial, 870
 triangle, 592
 Digastric muscle, 439
 Digestive apparatus, 1045
 development of, 128
 lymphatic vessels of, 730
 tube, 1045
 Digital arteries, common volar,
 627
 proper volar, 627
 articulations of foot, 420
 applied anatomy of, 420
 of hand, 387
 fossa of epididymis, 1165
 nerves of lateral plantar, 924
 of medial plantar, 923
 of median, 903
 of radial, 905
 of ulnar, 904
 vaginal ligaments, 493, 539
 veins of foot, 695, 698
 of hand, 687, 690

INDEX

naris anterior, 430
 anterior, 429
 nilla, 959
 tubæ, 988
 Diploë, 161
 Diploic veins, 678
 frontal, 678
 occipital, 679
 temporal, anterior, 678
 posterior, 678
 Diplopia, 852
 Direct cerebellar tract, 756
 division of cells, 2
 inguinal hernia, 1126
 pyramidal tract, 754
 Disc, articular, 344
 embryonic, 50
 optic, 961
 Discharge of ovum, 1181
 Discs, tactile of Merkel, 1005
 Discus proligerus, 1181
 Dislocation of—
 acromioclavicular joint, 368
 ankle-joint, 413
 atlas from epistropheus, 358
 elbow-joint, 379
 head of radius, 379
 hip-joint, 398
 congenital, 399
 knee-joint, 408
 long tendon of Biceps brachii, 400
 mandible, 348
 menisci of knee-joint, 408
 radiocarpal joint, 384
 shoulder-joint, 372
 sternoclavicular joint, 366
 subtalar, 418
 tarsal bones, 418
 wrist-joint, 384
 Dissociation of sensations, 838
 Diverticulum, Meckel's, 57, 1110
 Division of cells, direct, 2
 indirect, 2
 Divisions of bronchi, 1041
 anterior, of spinal nerves, 891
 posterior, of spinal nerves, 887
 Dobie's line, 31
 Dogiel, cells of, 885
 Dolichofacial, 261
 Dorsal antibrachial muscles, 496
 aorta, 120
 artery of penis, 647
 branch of ulnar nerve, 903
 carpal artery of radial, 622
 of ulnar, 625
 ligament, 503
 network, 622
 cutaneous nerve of foot, intermediate, 925
 lateral, 923
 medial, 925
 digital veins, 687, 695
 interosseous artery, 625
 lamina, 87
 mesogastrium, 135
 metacarpal arteries, 623
 veins, 687
 metatarsal veins, 695
 nasal artery, 598
 nerve of clitoris, 926
 nerve of penis, 926
 part of pons, 773
 peripheral band, 758
 radiocarpal ligament, 381

Dorsal scapular nerve, 896
 segmental arteries, 121
 veins of penis, 701
 venous arch of foot, 695
 venous network of hand, 687
 Dorsales linguae arteries, 582
 Dorsalis hallucis artery, 666
 pedis artery, 665
 applied anatomy of, 666
 branches of, 666
 peculiarities of, 666
 surface marking of, 1262
 scapulae artery, 616
 Dorsoepitrochlearis brachii muscle, 480
 Dorsum illi, 298
 nasi, 943
 of tongue, 1065
 sellæ, 198
 Douglas, pouch of, 1087, 1186
 Droplet, enamel, 1061
 Duct or ducts—
 accessory pancreatic, 141, 1132
 of Bartholin, 1052
 of Bellini, 1148
 of bulbo-urethral glands, 1178
 cloacal, 130
 common bile, 1141
 of Cuvier, 113, 123
 cystic, 1141
 ejaculatory, 1170
 frontonasal, 216
 of Gärtner, 147, 1181
 hepatic, 1140
 lacrimal, 977
 lactiferous, 1193
 of liver, 1140
 lymphatic, right, 712
 Müllerian, 149
 nasolacrimal or nasal, 978
 pancreatic, 141, 1131
 parotid, 1050
 pronephric, 146
 prostatic, 1161, 1177
 of Rivinus, 1052
 of Santorini, 1132
 semicircular, 998
 Skene's, 153
 Stensen's, 150
 sublingual, 1052
 submaxillary, 1052
 thoracic, 710
 thyroglossal, 131, 1065
 vitelline, 56, 57, 133
 Wharton's, 1052
 of Wirsung, 1131
 Wolffian, 146
 Ductless glands, 1195
 aortic bodies of Zucker-
 kandi, 1208
 glomera carotica, 1207
 glomus coccygeum, 1207
 parathyroids, 1198
 spleen or lien, 1200
 suprarenals, 1205
 thymus, 1198
 thyroid, 1195
 Ductuli aberrantes of testis, 1169
 efferentes of testis, 1167
 transversi of epoöphoron, 147, 1181
 Ductus artericus, 566, 568
 choledochus, 1141
 cochlearis, 998
 deferens, 1168

Ductus deferens, ampulla of, 1168
 artery to, 644
 lymphatics of, 735
 structure of, 1169
 endolymphaticus, 993, 997
 longitudinalis epoöphori, 1181
 Santorini, 1132
 utriculosaccularis, 997
 venosus, 123, 568
 development of, 123
 fossa for, 1134
 Wirsungi, 1131
 Duodenal fossæ, 1097
 flexure, inferior, 1106
 superior, 1106
 glands, 1112
 impression, 1137
 Duodenojejunal flexure, 1106, 1108
 fold, 1097
 fossa, 1097
 Duodenomesocolic fold, 1097
 Duodenopyloric constriction, 1099
 Duodenum, 1106
 ascending portion, 1108
 descending portion, 1107
 horizontal portion, 1107
 superior portion, 1106
 lymphatic vessels of, 731
 suspensory muscle of, 1108
 vessels and nerves of, 1108
 Dupuytren's contraction, 505
 Dura mater, 839
 cerebral, 839
 arteries of, 841
 endosteal layer of, 839
 meningeal layer of, 839
 nerves of, 841
 processes of, 840
 structure of, 841
 veins of, 841
 spiral, 841
 Ear, 979
 auditory (Eustachian) tube, 988
 auricula or pinna, 979
 cartilaginous capsules of, 75
 cochlea, 994
 external, 979
 external acoustic meatus, 981
 development of, 108
 internal, or labyrinth, 993
 applied anatomy of, 1004
 development of, 106
 membranous labyrinth, 996
 middle, or tympanic cavity, 984
 muscles of tympanic cavity, 990
 osseous labyrinth, 993
 ossicles of tympanic cavity, 988
 semicircular canals, 994
 tympanic cavity, 984
 applied anatomy of, 992
 vessels and nerves of, 991
 vestibule, 993
 Ear-capsules, chondrification of, 75
 Eberstaller, medial frontal sulcus of, 808
 Ectoderm, 50, 51
 amniotic, 61

INDEX

Ectodermal cloaca, 139
 Ectopic gestation, 1183
 Ectropion, 978
 Efferent lymphatic vessels, 708
 nerves, 742
 Ejaculator urinae muscle, 473
 Ejaculatory ducts, 1170
 Elastic fibres of areolar tissue, 8
 fibrocartilage, 17
 laminae of cornea, 954
 membrane of larynx, 1020
 tissue, yellow, 11
 Elastin, 12
 Elbow-joint, 373
 anastomoses around, 619
 applied anatomy of, 379
 movements of, 378
 surface anatomy of, 1246
 marking of, 1250
 vessels and nerves of, 376
 Eleidin, 8, 1009
 Element, sarcoous, 32
 Elephantiasis, 710
 Eleventh thoracic vertebra, 169
 rib, 189
 Embryo, formation of, 55
 form of, at different stages, 156
 Embryology, 41
 Embryonic disc, 50
 ectoderm, 50
 pole, 49
 Eminence, canine, 224
 collateral, 819
 cruciate, 194
 frontal, 213, 241, 248
 hypotenar, 500
 iliopectineal, 301, 303
 intercondyloid, of tibia, 318
 medial, of rhomboid fossa, 785
 Müllerian, 149
 parietal, 211, 241, 245
 pyramidal of tympanic cavity, 987
 thenar, 500
 Eminences and depressions of bones, 161
 Eminentia arcuata, 206
 articularis, 203
 sacularis, 800
 Emissary veins, 686
 applied anatomy of, 687
 Emphysema, pulmonary, 192
 surgical, 1043
 Empyema, 1034
 Enamel cells, 1061
 droplet, 1061
 epithelium, 1061
 fibres or prisms, 1059
 organs, 1061
 of teeth, 1059
 formation of, 1061
 pulp, 1061
 Enarthrosis, 345
 Encephalocoele, 262
 Encephalon, 766
 Encysted calculi, 1180
 hydrocoele of the cord, 1168
 End-arteries, 1150
 End-bulbs of Krause, 1005
 articular, 1006
 End-organs, special, of nerves, 1005
 End-plate, motor, 743
 Endocardial cushion, 115
 Endocardium, 562

Endognathion, 264
 Endolymph, 996
 Endomysium, 30
 Endoneurium, 741
 Endopelvic part of pelvic fascia, 469
 Endoskeleton, 160
 Endosmosis, 27
 Endosteal layer of dura mater, 839
 Endothelium, 4
 of anterior chamber of eye, 955
 Engelmann, basal knobs of, 5
 Enlargements of medulla spinalis, 746
 Enterectomy, 1124
 Enteroptosis, 1127
 Entoderm, 51
 Entodermal cloaca, 139
 Entrance to the larynx, 1023
 Entropion, 978
 Eneucleation of tonsils, 1072
 Eosinophil corpuscles, 28
 Eparterial branch of right bronchus, 1028, 1041
 Ependymal layer, 86, 815
 Epicardium, 551, 562
 Epicondyles of femur, 314
 of humerus, 278
 Epicranial aponeurosis, 427
 Epicranius, 426
 Epidermic coat of hair follicle, 1013
 Epidermis, development of, 84
 structure of, 1008
 Epithelium, 1164
 appendix of, 1165
 body of, 1164
 head of, 1164
 ligaments of, 1165
 sinus of, 1165
 tail of, 1164
 pidural space, 841
 Epigastric artery, deep or inferior, 652
 applied anatomy of, 652
 peculiarities, 652
 surface markings of, 1240
 superficial, 657
 superior, 609
 fold, 1125
 lymph-glands, 725
 region, 1084
 vein, inferior, 699
 superficial, 696
 Epiglottis, 1018
 tubercle or cushion of, 1019
 Epiphyseal bone, 441
 Epimysium, 30
 Epineurium, 741
 Epitotic centre of temporal bone, 210
 Epiphyseas, atavistic, 24
 pressure, 24
 traction, 24
 Epiphyseal cartilage, 22, 23
 Epiphysis, 24, 160
 actively growing, 25
 Epiphysitis, acute, 25
 Epiploic foramen, 136, 1091
 Epispadias, 1156, 1163
 Epistropheus or axis, 165
 development of, 177
 Epithalamus, 85, 797
 fœdalis retroflexus of Meynert, 797
 ganglion habenulae, 797

Epithalamus (cont.)
 habenular commissure, 797
 pineal body, 798
 applied anatomy of, 798
 structure of, 798
 posterior commissure, 798
 nucleus of, 798
 trigonum habenulae, 797
 Epithelial cells, 4
 sheath, 1063
 Epithelium, 4
 ciliated, 5
 columnar, 4
 corneal, 954
 cylindrical, 4
 enamel, 1061
 glandular, 5
 pavement, 4
 pigmented, 13
 simple squamous, 4
 stratified, 6
 transitional, 7, 1142
 Epitrichium, 84
 Epitympanic recess, 206, 984
 Eponeurium, 85, 1011
 Epophoron, 147, 1181
 Equator of lens, 965
 Erb's paralysis, 900
 Erector clitoridis muscle, 476
 penis muscle, 474
 spinæ or sacrospinalis muscle, 445
 Eruption of the teeth, 1063
 Erythroblasts, 27
 Erythrocytes, 26
 Ethmoidal air-cells, 218, 949
 arteries, 599
 bone, 217
 conchæ of, 219
 crista galli of, 217
 labyrinth or lateral mass of, 218
 lamina cribrosa of, 217
 lamina papyracea of, 218
 lamina perpendicularis of, 218
 os planum of, 218
 ossification of, 220
 uncinate process of, 219
 canals, 216, 218
 foramina, 250
 nerve, anterior, 855
 posterior, 856
 notch, 218
 process of inferior nasal concha, 220
 spine, 197
 sulcus, 222
 Eustachian tube, 988
 valve, 556, 701
 Excavation of optic nerve, 961
 recto-uterine, 1087, 1186
 rectovesical, 1087
 vesico-uterine, 1087, 1184
 Excision of ankle, 414
 elbow, 379
 hip, 399
 knee, 409
 shoulder, 373
 Excretory apparatus of the liver, 1140
 Exner, plexus of, 329
 Exophthalmos, 973
 Exoskeleton, 160
 Extensor carpi radialis brevis, 496
 longus, 496
 naris, 496

Extensor coccygis, 448
digiti quinti proprius, 497
digitorum brevis, 537
 communis, 497
 longus, 528
hallucis brevis, 537
 longus, 528
indicii proprius, 500
ossis metacarpi pollicis, 499
pollicis brevis, 499
 longus, 499
Exterior of skull, 241
External capsule of brain, 822
Extra-embryonic coelom, 50
Extraperitoneal connective tissue, 466
Extremities, 265
 bones of the inferior, 298
 of the superior, 266
Extrinsic muscles of tongue, 1067
Extroversion of bladder, 308, 1159
Eyeball, or bulb of the eye, 951
 accessory organs of, 968
 applied anatomy of, 966
 aqueous humour, 964
 capsule of Tonon, 972
 chambers of, 958
 chorioid, 953
 ciliaris muscle, 958
 ciliary body, 957
 processes, 957
 conjunctiva, 976
 cornea, 952
 crystalline lens, 965
 development of, 102
 fascia bulbi, 972
 fibrous tunic, 951
 filtration angle, 953
 iridial angle, 953
 iris, 958
 membrana pupillaris, 105, 958
 ocular muscles, 968
 orbiculus ciliaris, 957
 pupil, 958
 refracting media, 964
 retina, 960
 pigmented layer of, 961
 supporting framework of, 963
 retina proper, 961
 solera, 951
 tunics of, 951
 vascular tunic, 955
 vessels and nerves of, 966
 vitreous body, 964
Eyebrows, 973
Eyelashes, 974
Eyelids, 973
 applied anatomy of, 978
 development of, 105
 structure of, 974
 surface anatomy of, 1220
 tarsi of, 974
Eye-teeth, 1057
Face, bones of, 224
 development of, 79
 lymphatic vessels of, 716
 surface anatomy of, 1216
Facial artery, 582
 transverse, 586
bones, 224
canal, 207
 hiatus of, 207
 prominence of, 986

Facial hemiatrophy, progressive, 941
lymph-glands, 714
 deep, 714
nerve, 867
 motor root, 867
 sensory root, 868
 applied anatomy of, 871
vein, anterior, 673
 applied anatomy of, 674
 common, 673
 deep, 674
 posterior, 674
 transverse, 674
Falciform ligament of liver, 1086
 margin of fossa ovalis, 516
 cornua of, 517
 process of sacrotuberous ligament, 389
Fallopian tubes, 1182
False ligaments of bladder, 1157
 ribs, 186
 vertebrae, 161
 vocal cords, 1023
Falx cerebelli, 841
 cerebri, 840
 inguinal aponeurotic, 463
Fascia of abdomen, 456
 anal, 468
 of ankle, 535
 antibrachial, 491
 axillary, 491
 bicipital, 489
 brachial, 488
 buccopharyngeal, 436
 bulbi, 972
 of Camper, 457
 cervical, deep, 435
 superficial, 435
 of Colles, 458, 473
 colli, 435
 applied anatomy of, 437
 coracoclavicular, 483
 cromasteric, 462, 1171
 cribrosa, 516
 cruris, 528
 deep, 425
 deep cervical, 435
 of forearm, 491
 of leg, 528
 transverse of leg, 528, 531
 of deltoidens, 485
 dentata hippocampi, 813, 833
 diaphragmatic part of pelvic, 468
 dorsalis pedis, 537
 endopelvic, 469
 general description of, 425
 of the head, 426
 iliaca, 513
 iliopectineal, 513
 inferior of urogenital diaphragm, 475
 infraspinata, 487
 infundibuliform, 465, 1171
 intercrural, 459, 1171
 ischiorectal, 472
 lati, 516
 falciform margin of, 516
 fossa ovalis of, 516
 iliotibial tract or band of, 516
 of leg, 528
 deep transverse, 528, 531
 lumbo-dorsal, 444

Fascia, nuchal, 444
 of obturator internus, 467
 orbital, 972
 parotideomasseteric, 435
 pectoral, 481
 pelvic, 467
 pharyngobasilar, 1077
 pretracheal, 437
 prevertebral, 436
 propria of femoral hernia, 1127
 of piriformis, 467
 of psoas and iliacus, 513
 of quadratus lumborum, 466
 rectal, 469
 rectovesical, 469
 renal, 1146
 of Scarpa, 457
 Sibson's, 1033
 spermatic, external, 459, 1171
 subscapular, 486
 superficial, 425
 superior, of urogenital diaphragm, 476
 suprahypoid, 440
 supraspinata, 486
 temporal, 433
 of thigh, 516
 of thoracic region, 481
 transversalis, 465
 of trapezius, 478
 triangular, 460
 of upper extremity, 478
 of urogenital diaphragm, 475, 476
 in female, 477
 of urogenital region, 475, 476
 vesical, 469
Fascia, general description of, 425
Fasciculated bladder, 1160
Fasciculi, infrafasal, 1007
 superficial transverse of hand, 505
Fasciculus, anterior proper, or anterior basis bundle, 755
 of Burdach, 756
 cerebello-olivary, 769
 cerebellospinal of Löwenthal, 755
 cerebro-olivary, 769
 cerebrospinal, anterior, 754
 lateral, 755
 uncrossed, 755
 comma-shaped, 758
 cornucommissural, 757
 crossed pyramidal, 756
 cuneatus, 756
 direct cerebellar, 756, 767
 direct pyramidal, 754
 dorsal peripheral band, 758
 of Flechsig, 756
 of Goll, 756
 of Gowers, 756
 gracilis, 756
 of Helweg, 756
 inferior longitudinal, 829
 lateral proper, or lateral basis bundle, 756
 of Lissauer, 756
 of Löwenthal, 756
 medial longitudinal, 790
 of Monakow, 755
 occipitofrontal, 829
 olfactory, 825

Fasciculus, olivospinal, 756
 oval area of **Flechsig**, 758
 perpendicular, 820
 posterior longitudinal, 790
 pyramidal, crossed, 755
 direct, 754
 retroflexus of **Meynert**, 797
rubrospinal, 755
 secondary sensory, 756
 solitarius, 772, 875
 spinocerebellar, anterior, 756
 spino-olivary, 769
 spinotectal, 756
 spinothalamic, 756
 superficial anterolateral, 756
 superior longitudinal, 828
 tectospinal, 755, 756, 791
 thalamomamillary, 799, 824
 triangular strand, 758
 uncinata, 828
 vestibulospinal, 755
Fasciola cinerea, 813
Fastigium, 780
Fat or adipose tissue, 9
 cells, 9
Fauces, 1072
 arches or pillars of, 1072
Female genital organs, 1178
 bulb of vestibule, 1192
 caruncle hymenales, 1192
 clitoris, 1192
 development of, 145
 epoöphoron, 1181
 external, 1191
 Fallopian tubes, 1182
 fourchette, 1192
 greater vestibular glands,
 or glands of **Bartholin**,
 1192
 hymen, 1192
 labia majora, 1191
 minora, 1191
 mons pubis, 1191
 navicular fossa, 1192
 ovaries, 1178
 paroöphoron, 1181
 pronucleus, 43
 uterine tubes, 1182
 uterus or womb, 1183
 vagina, 1190
 vestibule, 1192
Female urethra, 1163
Femoral artery, 653
 applied anatomy of, 656
 branches of, 657
 peculiarities of, 656
 surface marking of, 1262
 canal, 654
 circumflex artery, lateral,
 658
 medial, 658
 cutaneous nerve, interme-
 diate, 916
 lateral, 913
 medial, 916
 posterior, 920
 fossa, 654
 fovea, 1125
 hernia, 1126
 nerve, 916
 applied anatomy of, 927
 ring, 654
 septum, 654
 sheath, 653
 triangle, 654
 vein, 698
Femur, 309
 applied anatomy of, 316

Femur, condyles of, 313
 head of, 310
 neck of, 310
 ossification of, 316
 structure of, 315
 surface anatomy of, 1254
 trochanters of, 311, 312
Fenestra vestibuli or ovalis,
 986
 basalis, 77
 narina, 77
 rostroventralis, 77
 cochleæ or rotunda, 986,
 996
Fenestrated membrane, 11
Fertilisation of ovum, 47
Fibræ propriæ of cerebellum,
 781
Fibres, external arcuate, 709
 association, of cerebellum,
 781
 of cerebrum, 828
 cerebrospinal, of internal
 capsule, 822
 clinging or tendril, of cere-
 bellum, 782
 commissural, of cerebellum,
 781
 of cerebrum, 828
 corticostriate, 820
 crossed commissural, 751
 dental, 1059
 enamel, 1059
 geniculate, of internal cap-
 sule, 822
 intercolumnar, 459
 intercural, 459
 internal arcuate, 767
 intrafusal, 1007
 moss, of cerebellum, 782
 muscle, 30
 nerve, 37
 osteogenetic, 22
 perforating, of bone, 20
 projection, of cerebellum, 778
 of cerebrum, 828
 of **Purkinje**, 34
 radial, of cerebral cortex, 831
 of **Remak**, 40
 sustentacular, of **Müller**, 903
 tangential, of cerebral cortex,
 831
 of **Tomes**, 1059
 white, of areolar tissue, 7
 yellow or elastic, of areolar
 tissue, 8
Fibrinoid substance of placenta,
 66
Fibrocartilage, circumferential,
 16
 connecting, 16
 interarticular, 16
 sacrococcygeal, 352
 stratiform, 17
 white, 16
 yellow or elastic, 17
Fibrocartilages, intervertebral,
 350
 applied anatomy of, 351
 semilunar of knee, 404
 structure of, 350
**Fibrocartilaginous lamina, in-
 terpubic**, 391
Fibrous capsule of Glisson,
 1094, 1138
 capsule of kidney, 1147
 pericardium, 551
 rings of heart, 562

**Fibrous sheaths of flexor ten-
 dons of fingers**, 493
 of toes, 539
 stratum of articular capsule,
 342
 tissue, white, 10
 tunic of eyeball, 951
Fibula, 322
 applied anatomy of, 324
 ossification of, 324
 surface form of, 1255
Fibular artery, 667
 collateral ligament of knee-
 joint, 403
 intermuscular septa, 528
 notch, 320, 321
Fifth lumbar vertebra, 170
 metacarpal bone, 296
 metatarsal bone, 337
Fillet or lamniscus, 767
 lateral, 790
 mesial, 791
Filtration angle of eye, 953
 applied anatomy of, 968
Filum terminale, 746, 840
Fimbria hippocampi, 825
 ovarian, 1182
Fimbriæ of uterine tube, 1182
**Fimbriated end of uterine
 tube**, 1182
Fimbriodentate fissure, 813,
 825
Finger-prints, 1008
First cervical vertebra, 164
 cervical nerve, anterior divi-
 sion, 891
 posterior division, 887
 cuneiform bone, 333
 ossification of, 338
 dorsal metacarpal artery,
 623
 metatarsal artery, 666
 metacarpal bone, 294
 metatarsal bone, 336
 plantar interosseous muscle,
 539
 rib, 188
 thoracic vertebra, 168
 volar interosseous muscle,
 506
Fissura antitragohelicina, 981
 prima of cerebellum, 93
 of olfactory lobe, 813
 secunda of cerebellum, 93
 vestibuli, 996
**Fissure, anterior median, of
 medulla spinalis**, 747
 chorioid, 102
 external rhinal, 96
 fimbriodentate, 813, 825
 flocular, 93
 Glaserian, 204, 985
 orbital, inferior, 246
 superior, 200, 251, 253
 petro-occipital, 244
 petrosphenoidal, 244
 petrotympanic, 204, 243,
 985
 postnodular, 93
 pterygoid, 201
 pterygomaxillary, 247
 sphenomaxillary, 246
 transverse of liver, 1135
**Fissure and sulci of medulla
 spinalis**, 747
Fissures of cerebellum, 776
 development of, 93
 flocular, 93

Fissures of cerebellum (*cont.*)

- horizontal, 776
- postcentral, 776
- postnodular, 93, 777
- postpyramidal, 777
- precentral, 776
- preclival, 777
- prepyramidal, 777
- of cerebral hemisphere, 806
 - development of, 98
 - calcarine, 807
 - callosal, 811
 - collateral, 807
 - complete and incomplete, 805
 - external rhinal, 96
 - fibriodontate, 813, 825
 - hippocampal, 98, 812
 - interlobar, 806
 - lateral cerebral, 99, 800
 - longitudinal cerebral, 805
 - parieto-occipital, 807
 - of Rolando, 806
 - of Sylvius, 806
 - transverse, 827
- congenital, of cranium, 224
- of lungs, 1040
- of medulla oblongata, 761, 762
- Fixation muscles, 424
- Fixed vertebrae, 161
- Flat bones, 160
- Flat-chest, 192
- Flat-foot, 417, 422
- Flechsig, direct cerebellar tract of, 756
- oval area of, 758
- Flexor accessorius muscle, 539
- carpi radialis, 492
- ulnaris, 492
- digiti quinti brevis of foot, 540
- of hand, 508
- digitorum brevis, 538
- longus, 532
- profundus, 493
- sublimis, 493
- hallucis brevis, 530
- longus, 532
- pollicis brevis, 506
- longus, 494
- Flexure, cervical, of brain, 91
- duodenal, inferior, 1106
- superior, 1106
- duodenojejunal, 1106, 1108
- hepatic, 1114, 1117
- left colic, 1114, 1118
- perineal, of rectum, 1122
- pontine, 91
- right colic, 1114, 1117
- sacral, of rectum, 1122
- splenic, 1114, 1118
- ventral cephalic, 90
- Floating kidney, 1161
- ribs, 186
- Floccular fissure, 93
- Flocculus, 777
- Floor-plate, 86
- Fluid, amniotic, 62
- cerebrospinal, 844
- vitelline, 57
- Fluids, circulating, 26
- blood, 26
- lymph, 29
- Fetal circulation, 566
- heart, peculiarities of, 127
- membranes, 59
- portion of placenta, 66
- Fetus, circulation in, 566
- foramen ovale in, 115, 566
- peculiarities of vascular system in, 566
- valve of inferior vena cava in, 557, 566
- Fold, aryepiglottic, 1023
- caudal, 55
- cephalic, 55
- duodenojejunal, 1097
- duodenojejunal, 1097
- iliocacal, 1098
- inguinal, 161
- patellar, 401
- salpingopalatine, 1076
- salpingopharyngeal, 1076
- of Treves, 1098
- urogenital, 147
- vestigial, of Marshall, 126, 552
- Folds, alar, of synovial stratum of knee-joint, 401
- amniotic, 61*
- circular, of small intestine, 1110
- epigastric, 1125
- glossopiglotitic, 1019, 1004
- malleolar, 985
- neural, 53
- palmar, of cervix uteri, 1185
- recto-uterine, 1186
- rectovesical, 1089
- sacrogenital, 1089, 1186
- transverse, of rectum, 1120
- umbilical, 1125, 1157
- ventricular, of larynx, 1023
- vocal, of larynx, 1023
- Folium vernis or cacuminis, 777
- Follicle of hair, 1012
- Follicles, Graafian, or vesicular ovarian, 1180
- Fontana, spaces of, 955
- Fontanelles, 258
- Fonticulus, frontal or anterior, 212, 258
- mastoid, 258
- occipital or posterior, 195, 212, 258
- sphenoidal, 258
- Foot, arches of, 420
- applied anatomy of, 422
- dorsal fascia of, 537
- muscle of, 537
- ossification of bones of, 338
- plantar muscles of, 537
- skeleton of, 325
- applied anatomy of, 340
- surface anatomy of, 1255
- Foot-drop, 928
- Foramen bursa omenti majoris, 1092
- cæcum of frontal bone, 215
- of medulla oblongata, 761
- of tongue, 130, 1065
- caroticooclinoid, 201
- condyloid, anterior, 195
- epiloicum, 136, 1091
- frontal, 214
- of Huschke, 209, 211
- incisive, 228, 243
- infraorbital, 224
- interventricular, 803, 825
- jugal, 244, 255
- lacerum, 244, 254
- magnum, 193, 196, 244, 255
- Majendro, 785, 843
- mandibular, 236
- Foramen mastoid, 205
- mental, 235, 249
- of Monro, 803, 825
- nutricium, 18
- obturator, 303
- optic, 197, 201
- ovale of heart, 115, 566
- of sphenoid, 200, 243, 254
- palatine, greater, 243
- parietal, 211
- rotundum, 200, 254
- sciatic, greater, 390
- lesser, 390
- singulare, 207
- sphenopalatine, 232
- spinous, 200, 243, 254
- sternal, 182
- stylomastoid, 208, 243
- supraorbital, 214, 248, 249
- supratrochlear, 277
- transversarium, 163
- vena-caval, in diaphragm, 453
- vertebral, 161
- Vesalii, 200, 254
- of Winslow, 136, 1091
- zygomatofacial, 233, 248
- zygomatocotemporal, 233, 240
- Foramina, ethmoidal, 250, 252
- intervertebral, 161
- palatine, lesser, 243
- in roof of fourth ventricle, 785
- sacral, anterior, 171
- posterior, 172
- of Scarpa, 228, 243
- of Stensen, 228, 243
- venarum minimarum, 556, 560
- zygomatoco-orbital, 234
- Forceps, anterior, 815
- posterior, 815
- Forearm, muscles of, 491
- veins of, 687, 690
- Forebrain, 53, 93, 793
- Foregut, 56, 128
- Foreskin, 1174
- Form of embryo at different stages, 166
- Formatio reticularis of medulla oblongata, 771
- of medulla spinalis, 749
- Formation of mesoderm, 50
- of embryo, 55
- Formative yolk, 41
- Fornices of vagina, 1190
- Fornix of brain, 823
- body of, 824
- columns of, 824
- crura of, 825
- development of, 98
- ventricle of, 824
- Fornix inferior, of conjunctiva, 976
- superior, 976
- Fossa, acetabular, 303
- anterior, of skull, 252
- cæcal, 1097
- canine, 224
- occhilearis, 993
- condyloid, 196
- coronoid, 277
- cubital, 617
- digastric, of mandible, 235
- of temporal bone, 205
- digital, of epididymis, 1165
- for ductus venosus, 1124
- duodenal, inferior, 1097
- superior, 1097

Fossa, duodenojejunal, 1097
 femoral, 664
 for gall-bladder, 1134
 glenoid, 203
 hyaloid, 964
 hypophyseal, 197, 253
 ileocecal, inferior, 1097
 superior, 1097
 iliac, 299
 incisive, 224, 235
 incudis, 987
 for inferior vena cava, 1135
 infraclavicular, 483
 infraspinatus, 267
 infratemporal, 246
 intercondyloid, of femur, 314
 of tibia, 320
 interpeduncular, 803
 intersigmoid, 1098
 ischio-rectal, 472
 jugular, 208, 209
 lacrimal, 215, 227
 mandibular, 203, 243, 246
 middle, of skull, 252
 navicularis of urethra, 1162
 of vestibule, 1192
 occipital, inferior, 255
 olecranon, 277
 ovalis of heart, 557
 of fascia lata, 516
 ovarian, 1090, 1178
 pararectal, 1089
 paravesical, 1039, 1154
 popliteal, 660
 posterior, of skull, 254
 pterygoid, 201
 pterygopalatine, 247
 radial, 277
 retrocaecal, 1098
 rhomboid, 785
 of Rosenmüller, 79, 1077
 scaphoid, 201, 243
 of skull, anterior, 252
 middle, 252
 posterior, 254
 sphenomaxillary, 247
 subarcuate, 207
 subscapular, 266
 supraspinatus, 267
 supratonsillar, 1072
 Sylvian, 99
 temporal, 245
 triangularis, 979
 trochanteric, 311
 for umbilical vein, 1134
 vermian, 194

Fosse, caecal, 1097
 duodenal, 1097
 intercondyloid, of tibia, 320
 of liver, 1134
 peritoneal, 1097
 applied anatomy of, 1098
 sagittal, of liver, 1134
 of skull, 252

**Fountain decussation of Mey-
 nert, 792**

Fourchette, 1192

Fourth metacarpal bone, 295
 metatarsal bone, 337
 ventricle, 783

Fovea capitis femoris, 310
 centralis retinae, 981
 structure of, 964
 dentia, 164
 femoral, 1125
 inferior, of rhomboid fossa,
 786
 inguinal, lateral, 1125

Fovea, inguinal, medial, 1125
 pterygoid, 237
 superior, of rhomboid fossa,
 786
 supravesical, 1125
 trochlearis, 215, 249

Foveola, Howship's, 23

Fracture, 'greenstick,' 273

**Fracture-dislocation of verte-
 bral column, 181**

Fracture or fractures of—
 acromion, 510
 bones of foot, 340
 of forearm, 286, 511, 512
 of hand, 298
 of leg, 324
 carpal bones, 298
 clavicle, 273, 510
 Colles, 287
 femur, 317, 542
 fibula, 324, 544
 humerus, 278, 510
 mandible, 265
 maxilla, 265
 metatarsal bones and pha-
 langes, 340
 nasal bone, 265
 olecranon, 286, 511
 patella, 325, 544
 pelvis, 308
 Pott, 544
 radius, 287, 511
 ribs, 191
 scapula, 271
 skull, 263
 sternum, 191
 tarsal bones, 340
 tibia, 324, 544
 ulna, 286, 512
 zygomatic arch, 265
 bone, 265

Free nerve-endings, 1005

Freely movable joints, 344

Fremitus, vocal, 1045

Frenula of colic valve, 1116
 of lips, 1046

Frenulum of clitoris, 1192
 of labia minora, 1192
 linguae, 1064
 of prepuce, 1174
 veli, 780, 792

Frommann's lines, 39

**Frontal air sinuses, 216, 949,
 1216**
 arteries, 586, 589
 bone, 213
 nasal part of, 214
 orbital part of, 215
 ossification of, 216
 squama of, 213
 structure of, 216
 crest, 215
 eminence, 213, 241, 248
 fonticulus, 212, 258
 foramen, 214
 gyri, 808
 lobe, 808
 nerve, 855
 notch or foramen, 214
 operculum, 811
 process of maxilla, 227
 spine, 214
 sulci, 808
 suture, 213, 248
 tuberosity, 213, 241, 248
 vein, 672

Frontalis, 427

Fronto-ethmoidal suture, 252

Frontomaxillary suture, 250

Frontonasal duct, 216
 process, 79

Frontopontine fibres, 788

**Frontosphenoidal process of
 zygomatic bone, 234**

**Fundiform ligament of penis,
 458, 1174**

Fundus of stomach, 1100
 glands of, 1104
 tympani, 985
 of urinary bladder, 1154
 of uterus, 1184, 1185

**Funicular process, hernia into,
 1126**

Funiculi of medulla spinalis—
 anterior, 754
 lateral, 755
 posterior, 756

Funiculus, nerve, 741
 separans, 786
 spermaticus, 1170

Funnel-breast, 192

Furcal nerve, 911

Furcula, 130, 142

Furrow, dental, 1060
 iliac, 1233
 naso-optic, 80, 106
 sternal, 1227

**Furrowed band of cerebellum,
 778**

Fusiform gyrus, 810, 811

Galactocoele, 1194

Galea aponeurotica, 427

Galen, veins of, 680

Gall-bladder, 1140
 applied anatomy of, 1142
 fossa for, 1134
 lymphatic vessels of, 732
 structure of, 1141

Ganglion or ganglia, 743
 aberrant, 885
 aorticorenal, 938
 cardiac, of Wrisberg, 937
 carotid, 937
 cervical, inferior, 933
 middle, 932
 superior, 932
 ciliary, 856
 coccygeal, 935
 coliac, 938
 compound palmar, 506
 of Corti, 1004
 Gasserian, 853
 genicular, 868, 869
 of glossopharyngeal, 875
 habenulae, 797
 impar, 935
 inferior mesenteric, 940
 interpeduncular, 787, 790
 jugular of glossopharyngeal,
 875
 of vagus, 878
 Langley's, 1053
 Meckel's, 858
 nodosum of vagus, 878
 otic, 862
 petrous, 875
 phrenic, 894, 938
 of Scarpa, 1004
 semilunar, of abdomen, 938
 of trigeminal nerve, 853
 sphenopalatine, 858
 spinal, 885
 spirals of cochlea, 872, 1004
 splanchnicum, 934
 stellate, 935

Ganglion or ganglia (*cont.*)
 structure of, 743
 submaxillary, 863
 superior of glossopharyngeal, 875
 superior mesenteric, 939
 of sympathetic nervous system, 928
 of vagus, 878
 vestibular, 872, 1004
 of Wrisberg, 928
Ganglion-ridge, 53, 88
Ganglionic arteries, antero-lateral, 600
 anteromedial, 599
 posterolateral, 608
 posteromedial, 601, 608
 arterial system of brain, 601
 layer of retina, 962
Gärtner, duct of, 147, 1181
Gasserian ganglion, 853
Gastric arteries, short, 635
 artery, left, 633
 right, 634
 canal, 135, 1101
 glands, 1104
 impression, 1136
 lymph-glands, superior, 726
 inferior, 727
 nerves from vagus, 881
 plexus, anterior, 881
 inferior, 939
 posterior, 881
 superior, 939
 veins, short, 705
Gastric vein, right, 706
Gastrocnemius muscle, 530
Gastrocolic ligament, 1087
Gastroduodenal artery, 634
Gastro-enterostomy, 1105
Gastro-epiploic artery, left, 635
 right, 634
 vein, left, 705
 right, 706
Gastrolleal ligament, 1091, 1201
Gastrop pancreatic ligament, 1093
Gastrophrenic ligament, 1100
Gastrosplenic omentum, 1091
Gastrostomy, 1105
Gastrotomy, 1105
Gelatinous nerve-fibres, 40
Gemellus, inferior, 525
 superior, 525
General sensations, peripheral terminations of nerves of, 1005
Generative organs, development of, 145
Genicular artery, highest, 660
 inferior, 663
 middle, 663
 superior, 662
 ganglion of facial nerve, 868
Geniculate body, lateral, 797
 medial, 796
 fibres of internal capsule, 822
Geniculum of facial nerve, 868
Genioglossus muscle, 1067
Geniohyoidens muscle, 441
Genital branch of genitocrural nerve, 913
Genital cord, 149
 corpuscles, 1066

Genital glands, 149
 organs of female, 1178
 external, 1191
 of male, 1164
 ridge, 149
 swellings, 154
 tubercle, 154
Genitals, external, lymphatic vessels of, 730
Genitofemoral or genitocrural nerve, 913
Gennari, band of, 830
Genu of corpus callosum, 814
 of internal capsule, 821
Genu valgum, 408
Gerlach, tube-tonsil of, 988
Germ, common dental, 1060
 special dental, 1060
Germ-centres, 709
Germinal cells, 41
 spot, 41, 42
 vesicle, 41, 42
Gestation, ectopic, 1183
Giacomini, band of, 813
Giant-cells, 28
 of Betz, 830
Gianuzzi, crescents of, 1053
Gimbernat's ligament, 460
Gingivæ, 1047
Ginglymus, 344
Giraldes, organ of, 1160
Girdle, of inferior extremities, 261
 pelvic, 265
 shoulder, 265
 of superior extremities, 265
Glabella, 214, 261
Gland or glands--
 accessory of mouth, 1053
 part of parotid, 1049
 accessory thyroid, 1196
 anterior lingual, 1070
 areolar, 1153
 arytenoid, 1027
 of Bartholin, 153, 1192
 of Blandin, 1070
 of Bowman, 946
 of Brunner, 1112
 buccal, 1046
 bulbo-urethral, 153, 1178
 cardiac, 1104
 ceruminous, 983
 ciliary, 974
 of Cowper, 153, 1178
 development of, 85
 ductless, 1195
 duodenal, 1112
 fundus, 1104
 gastric, 1104
 genital, 149
 greater vestibular, 153, 1192
 intestinal, 1112
 labial, 1046
 lacrimal, 976
 of larynx, 1027
 lenticular, of stomach, 1104
 of Littre, 1162
 mammae, 1192
 development of, 85
 Meibomian, 975
 molar, 1046
 of Nuhn, 1070
 oesophageal, 1082
 oxyntic, 1104
 parathyroid, 1198
 development of, 131
 parotid, 1049
 Peyer's, 1113

Gland or glands (*cont.*)
 preputial, 1174
 pyloric, 1104
 salivary, 1049
 development of, 130
 sebaceous, 1014
 development of, 85
 spleen or lien, 1200
 sublingual, 1052
 submaxillary, 1051
 sudoriferous, 1014
 development of, 85
 suprarenal, 1205
 development of, 101
 sweat, 1014
 development of, 85
 tarsal, 975
 thymus, 1198
 development of, 13
 thyreoid, 1195
 development of, 131
 of tongue, 1070
 trachoma, 976
 urethral, 1162
 uterine, 1189
 vestibular, greater, 153, 1192
Glandulæ Pacchioni, 844
Glandular branches of external maxillary artery, 584
 of inferior thyreoid artery, 610
Glandular epithelium, 5
Glans clitoridis, 1192
 penis, 1174
Glaserian fissure, 204, 985
Glaucoma, 968
Glenohumeral ligaments, 360
Glenoid cavity, 269
 fossa, 203
 ligament of shoulder, 370
 ligaments of Cruveilhier, 387, 420
Glenoidal labrum of hip-joint, 396
 of shoulder-joint, 370
Gliding movement, 345
Glisson's capsule, 1094, 1138
Globular processes, 80
Globus major of epididymis, 1164
 minor, 1164
 pallidus, 820
Glomera carotica, 1207
 structure of, 1207
Glomeruli of kidney, 1147
 of olfactory bulb, 834
Glomus coccygeum, 1207
 structure of, 1208
Glossa-epiglottic folds, 1019, 1064
Glossopalatine arch, 1072
Glossopalatinus, 1075
Glossopharyngeal nerve, 875
 motor fibres, 875
 sensory fibres, 875
Glottis respiratoria, 1024
 vocalis, 1024
 rima of, 1024
Gluteal arteries, 649, 650
 applied anatomy of, 651
 lines of ilium, 298, 299
 muscles, 522
 nerves, 920
 tuberosity, 312
 veins, 700
Gluteus maximus muscle, 522
 medius muscle, 522
 minimus muscle, 522

Gnathic index, 261
 Goblet or chalice cells, 5
 Goitre, 1197
 Golgi, cells of, 36
 organs of, 1007
 Golgi and Mazzoni, corpuscles of, 1007
 Goll, tract of, 756
 Gomphosis, 343
 Gonion, 261
 Gout, 420
 Gowers, tract of, 756
 Graafian follicles, 1180
 Gracile nucleus, 764
 Gracilis muscle, 519
 Grandry, tactile corpuscles of, 1006
 Granular layer of Tomes, 1059
 lida, 966
 Granulations, arachnoideal, 844
 Granule-cells, 9
 Granules, basophil, 29
 of Nissl, 36
 Great auricular nerve, 892
 cardiac vein, 672
 cerebral vein, 680
 saphenous vein, 695
 scapular notch, 268
 wings of sphenoid, 199
 Greater cavernous nerve, 940
 cornua of hyoid bone, 240
 curvature of stomach, 1099
 multangular bone, 292
 ossification of, 296
 occipital nerve, 888
 omentum, 1094
 palatine foramen, 243
 pelvis, 305
 sac of peritoneum, 1086
 sciatic foramen, 390
 notch, 301
 superficial petrosal nerve, 588, 869
 trochanter, 311
 tubercle of humerus, 274
 vestibular glands, 153, 1192
 Greenstick fracture, 273
 Grey commissures of medulla spinalis, 750
 Grey nerve-substance, 34
 Grey substance of cerebellum, 781
 of cerebral hemispheres, 829
 of medulla oblongata, 768
 of medulla spinalis, 748
 Grey or gelatinous nerve-fibres, 40
 Groove, auriculoventricular, 553
 bicipital, 274
 costal, 187
 infraorbital, 225
 interatrial, 553
 lacrimal, 221
 laryngotracheal, 142
 musonlospiral, 276
 mylohyoid, 236
 nasopalatine, 222
 neural, 53
 obturator, 303
 occipital, 205
 optic, 197
 primary labial, 129
 primitive, 50
 sacral, 172
 secondary labial, 129
 vertebral, 180

Grooves, branchial or outer
 pharyngeal, 77
 rhombic, 92
 Gubernaculum dentis, 1083
 testis, 151
 Gudden, commissure of, 802, 850
 Gullet, 1081
 Gum-boil, 1064
 Gums, 1047
 applied anatomy of, 1047
 spongy, 1047
 Gustatory calyculi, 942
 cells, 943
 hair, 942
 pore, 942
 Gut, post-anal, 139
 Gyrus or gyri—
 angular, 809
 anterior central, 808
 of Broca, 808
 cingulate, 811
 cuneus, 809
 dentate, 813, 833
 frontal, 808
 fusiform, 811
 hippocampal, 812
 of insula, 811
 of limbic lobe, 811
 lingual, 809
 marginal, 808
 occipital, 809
 orbital, 808
 posterior central, 809
 precentral, 809
 quadrate, 809
 rectus, 808
 subcallosal, 813
 superior parietal lobule, 809
 supracallosal, 813
 supramarginal, 809
 temporal, 810
 transverse temporal of Heschl, 810
 uncus, 812
 Habenular commissure, 797
 Hamatoma auris, 983
 Hamoblasts, 27
 Hæmorrhage, postpartum, 68
 Hæmorrhoidal artery, inferior, 647
 middle, 645
 superior, 638
 nerve, inferior, 926
 plexus of nerves, 940
 vein, middle, 700
 superior, 705
 venous plexus, 700
 applied anatomy of, 700
 Hair-bulb, 1012, 1014
 Hair-cells of spiral organ of Corti, 1002
 Hair-follicle, 1012
 dermic coat, 1013
 epidermic coat, 1013
 Hairs, 1012
 development of, 85
 gustatory, 943
 olfactory, 948
 structure of, 1012
 Haller, vas aberrans of, 1169
 Hallux rigidus, 420
 valgus, 420
 Hamate bone, 293
 ossification of, 296
 Hammer toe, 420

Hamstring tendons, applied anatomy of, 527
 Hamulus of hamate bone, 294
 lacrimal, 221
 lamina spiralis, 996
 pterygoid, 201, 243
 Hand, muscles of, 500
 skeleton of, 200
 surface anatomy of, 1246
 1249
 veins of, 687, 690
 Hard palate, 1048
 Hare-lip, 264
 Harrison's sulcus, 192
 Hasner, plica lacrimalis of, 978
 Hassall, concentric corpuscles of, 1200
 Haversian canals of bone, 19
 systems of bone, 19
 Head, lymph-glands of, 713
 lymphatic vessels of, 716
 muscles of, 426
 veins of, 672
 Head and neck, arteries of, 576
 Head-cap of spermatozoön, 44
 Hearing, organ of, 979
 Heart, 553
 actions of valves, 565
 applied anatomy of, 560
 atrioventricular node, 564
 bundle, 564
 cardiac cycle, 565
 component parts of, 553
 development of, 111, 113
 endocardium, 562
 fibres of the atria, 563
 of the ventricles, 563
 fibrous rings of, 562
 left atrium, 559
 ventricle, 560
 lymphatic vessels of, 738
 nerves of, 565
 os cordis, 562
 right atrium, 555
 ventricle, 558
 sino-atrial node, 564
 size and weight, 553
 structure of, 562
 surface marking of, 1231
 trigonum fibrosum, 562
 vessels of, 565
 ventricular septum, 561
 wounds of, 566
 Heart-block, 565
 Heidenhain, demilunos of, 1053
 Height index of skull, 261
 Helicine arteries, 1175
 Helicis major muscle, 981
 minor, 981
 Helicotrema, 995, 996
 Helix, 979
 Helweg, olivospinal fasciculus of, 756
 Hemizygos vein, 693
 accessory, 693
 Hemispheres, cerebellar, 775
 cerebral, 804
 Henle, loop of, 1148
 Henle's layer of hair follicle, 1013
 Hensen, canalis reuniens of, 997, 1000
 knot of, 50
 line of, 31
 stripe of, 1003
 supporting cells of, 1003
 Hepar, 1133
 Hepatic artery, 633, 1137, 1139

- Hepatic branches of vagus nerve, 881
 cylinders, 139
 duct, 1140
 flexure of colon, 1117
 lymph-glands, 727
 plexus, 939
 veins, 703, 1138
 Hepatoduodenal ligament, 1087, 1094
 Hepatogastric ligament, 1087, 1094
 Hepatorenal ligament, 1087, 1137
 Herbst, corpuscles of, 1007
 Hernia, 1124
 complete congenital, 1126
 femoral, 1126
 into funicular process or incomplete congenital, 1126
 inguinal, 1125
 direct, 1126
 oblique, 1125
 of lung, 1044
 scrotal, 1125
 testis, 1168
 Herophilus, torcular of, 194
 Heschl, gyri of, 850
 Hesselbach, interfoveolar ligament of, 463
 triangle of, 1126, 1240
 Heterotypical mitosis, 3
 Hiatus, aortic, 453
 of facial canal, 207
 oesophageal, 453
 sacralis, 172
 semilunaris, 257, 946
 Highmore, antrum of, 226, 950
 Hilum of inferior olivary nucleus, 769
 of kidney, 1142
 of lung, 1039
 of spleen, 1200
 Hind-brain, 53, 91, 761
 Hind-gut, 56, 128
 Hinge-joint, 344
 Hip-bone, 298
 ossification of, 304
 structure of, 304
 surface anatomy of, 1254, 1255
 Hip-disease, 398
 Hip-joint, 393
 applied anatomy of, 398
 movements of, 397
 muscles in relation with, 396
 Hippocampal commissure, 824
 fissure, 98, 812
 gyrus, 812
 Hippocampus, 98, 819
 structure of, 833
 His, atrioventricular bundle of, 34, 564
 globular processes of, 80
 Histology, 1
 Holoblastic ova, 48
 Homotypical mitosis, 3
 Horizontal cells of retina, 963
 circumference of skull, 261
 part of palatine bone, 230
 spices of cerebellum, 776
 Housemaid's knee, 409
 Houston's valves of rectum, 1120
 Howship's foveola, 23
 Huguier, canal of, 204, 985, 992
 Human ovum, 41
 Humeral articulation, 369
 applied anatomy of, 372
 bursa in relation to, 370
 movements of, 371
 vessels and nerves of, 371
 circumflex artery, anterior, 616
 posterior, 616
 ligament, transverse, 370
 Humerus, 274
 applied anatomy of, 278
 ossification of, 278
 structure of, 278
 surface anatomy of, 1245
 Humour, aqueous, 964
 Hunter's canal, 655
 Huschke, auditory teeth of, 1001
 foramen of, 209, 211
 Huxley's layer of hair-follicle, 1013
 Hyaline cartilage, 14
 cell, 28
 Hyaloid artery, 99
 canal, 99, 964
 fossa, 964
 membrane of eye, 965
 Hyaloplasm, 1
 Hydatid of Morgagni, 149, 1165, 1182
 pedunculated, of epididymis, 1165
 Hydrocele, 1168
 Hydrothorax, 1034
 Hymen, 1192
 Hypo-epiglottic ligament, 1019
 Hyoglossal membrane, 1070
 Hyoglossus muscle, 1067
 Hyoid arch, 77
 arteries, 580, 582
 bone, 240
 body of, 240
 cornua of, 240, 241
 ossification of, 241
 Hyothyroid ligaments, 1020
 membrane, 1020
 Hyparterial bronchi, 1028, 1043
 Hypernephroma, 1151, 1207
 Hypochondriac regions, 1084
 Hypohordal bar or brace, 71
 Hypoglossal artery, 644
 applied anatomy of, 644
 branches of, 644
 changes in, at birth, 568
 in foetus, 566
 peculiarities of, 644
 lymph-glands, 725
 plexus, 940
 region, 1084
 vein, 699
 Hypoglossal nerve, 882
 applied anatomy of, 884
 nucleus of, 768
 canal, 195
 membrane, 1070
 Hypophysial arteries, 596
 Hypophysis, 132, 800
 applied anatomy of, 801
 development of, 132
 lobes of, 800
 structure of, 800
 Hypospadias, 1163
 Hypothalami, pars mamillaris, 95
 pars optica, 95
 Hypothalamus, 798
 corpora mamillaris, 799
 hypophysis or pituitary body, 800
 Hypothalamus (*cont.*)
 infundibulum, 800
 optic chiasma, 802
 subthalamio tegmental region, 798
 corpus subthalamicum, 799
 stratum dorsale, 799
 zona incerta, 799
 tuber cinereum, 799
 Hypothenar eminence, 500
 Ichthyoid blood-cells, 110
 Ileal arteries, 636
 lymph-glands, 728
 Ileocaecal fossa, 1097
 fold, 1098
 Ileocolic artery, 638
 lymph-glands, 728
 Ileum, 1108
 lymphatic vessels of, 731
 Iliac arteries, common, 642
 applied anatomy of, 643
 peculiarities of, 643
 surface marking of, 1240
 external, 651
 applied anatomy of, 651
 surface marking of, 1240
 internal, 644
 applied anatomy of, 644
 branches of, 644
 peculiarities of, 644
 circumflex artery, deep, 652
 superficial, 657
 vein, deep, 699
 internal, 699
 superficial, 696
 colon, 1119*
 fascia, 513
 fossa, 299
 furrow, 1233
 lymph-glands, circumflex, 725
 common, 725
 external, 725
 region, 1084
 spines, 301
 tuberosity, 300
 vein, common, 701
 peculiarities of, 701
 external, 698
 internal, 699
 Iliacus muscle, 514
 fascia covering, 513
 Iliocaecal fossa, 1097
 fold, 1098
 Iliococcygeus muscle, 470
 Iliocostalis cervicis, 447
 dorsi, 447
 lumborum, 447
 Iliofemoral ligament, 395
 Iliohypogastric nerve, 912
 Ilio-inguinal nerve, 913
 Iliolumbar artery, 649
 ligament, 399
 Iliopsoas eminence, 301, 303
 fascia, 513
 Iliopsoas, 514*
 Iliosternalis, 470
 Iliotibial band or tract, 516
 Iliotrochanteric ligament, 395
 Ilium, 298
 ala of, 298
 body of, 298
 crest of, 300
 dorsum of, 298
 gluteal lines of, 298, 299

Ilium, spines of, 301
 Immovable articulations, 343
 Implantation or imbedding of fertilised ovum, 63
 Impression, cardiac, on liver, 1136
 on lung, 1039
 colic, 1136
 duodenal, 1137
 gastric, 1137
 oesophageal, 1136
 renal, 1136
 rhomboid, 272
 suprarenal, 1136
 trigeminal, 207
 Incisive bone, 229
 canals, 228, 236
 foramen, 228, 243
 fossa, 224, 235
 teeth, 1055
 Incisivus labialis inferioris, 432
 superioris, 432
 Incisor crest, 229
 Incisors, 1055
 Incisura angularis, 1099
 apicis cordis, 553
 cardiac, 1008
 ethmoidalis, 216
 fastigii, 93
 temporalis, 812
 tentorii, 841
 umbilicalis, 1134
 Ineus, 989
 body, 989
 crura, 989
 development of, 108
 lenticular process, 989
 ligaments of, 990
 Index, cephalic or breadth, 261
 dental, 262
 gnathic or alveolar, 261
 nasal, 261
 orbital, 261
 vertical or height, 261
 Indirect division of cells, 2
 Indusium griseum, 813
 Infantile hydrocele, 1168
 paralysis, 25, 760
 Inferior transverse ligament of scapula, 369
 Infraclavicular branches of brachial plexus, 897
 fossa, 483
 Infraglenoid tuberosity, 268
 Infrathyoid lymph-glands, 715
 muscles, 439
 Infraorbital artery, 500
 canal, 225
 foramen, 224
 groove, 225
 lymph-glands, 714
 nerve, 856*
 plexus of nerves, 858, 871
 Infrapatellar pad of fat, 401
 Infrascapular artery, 616
 Infraspinaous fossa, 267
 Infraspinaous muscle, 487
 Infrasternal notch, 1288
 Infratemporal crest, 200
 fossa, 246
 surface of maxilla, 224
 of sphenoidal bone, 200
 Infraorbital nerve, 856
 Infundibula of lungs, 1042
 Infundibuliform fascia, 465, 1171
 Infundibulopelvic ligament, 1186

Infundibulum of brain, 800
 of ethmoidal bone, 219, 257, 946
 of uterine tube, 1182
 Infusion, intravenous, 689
 Inguinal aponeurotic falx, 463
 canal, 465
 crest, 151
 fold, 151
 fovea, lateral, 1125
 medial, 1125
 lymph-glands, 722
 applied anatomy of, 723
 hernia, 1125, 1126
 ligament, 459
 reflected, 460
 regions, 1084
 ring, abdominal, 465
 subcutaneous, 458
 Inion, 261
 Inlet of pelvis, 305
 Inner cell-mass, 49
 Inner surface of skull-cap, 252
 Innominate artery, 575
 applied anatomy of, 575
 bone, 298
 ossification of, 304
 veins, 691
 peculiarities of, 691
 Inscriptions, tendinous, of rectus abdominis, 463
 Insertion of muscles, 424
 Insula, 811
 circular sulcus of, 811
 gyri of, 811
 opercula of, 811
 Integument, 1008
 Interalveolar cell-islets of pancreas, 1132
 Interarticular fibrocartilages, 16
 ligament of head of rib, 359
 sternocostal ligaments, 362
 Interatrial groove, 553
 Intercapitular veins, 687, 695
 Intercarpal articulations, 382
 movements of, 384
 Intercavernous sinuses, 685
 Interchondral articulations, 363
 ligaments, 363
 Interclavicular ligament, 366
 Interclinoïd ligament, 203
 Intercolumnar fibres, 459
 Intercondyloid eminence of tibia, 318
 line of femur, 314
 fossa of femur, 314
 fossæ of tibia, 320
 Intercostal arteries, from aorta, 629
 from internal mammary, 609
 artery, superior, 611
 lymph-glands, 735
 membranes, 450
 nerves, 908
 spaces, 186
 veins, 693
 Intercostal vein, left superior, 691
 right superior, 693
 Intercostales externi, 450
 interni, 450
 Intercostalis suprema artery, 611
 Intercostobrachial nerve, 910
 Intercural fascia, 456, 1171
 fibres, 459

Interuneiform articulations, 417
 Interfoveolar ligament of Hesselbach, 463
 Interglobular spaces, 1059
 Interior of cerebral hemispheres, 813
 of skull, 252
 of urinary bladder, 1158
 of uterus, 1185
 Interlobar fissures of cerebral hemispheres, 806
 Interlobular arteries of kidney, 1150
 plexuses, 1139
 Intermediate cell-mass, 52, 55
 Intermetacarpal articulations, 386
 Intermetatarsal articulations, 418
 Internal acoustic meatus, 207, 255
 capsule of brain, 821
 applied anatomy of, 834
 mammary artery, 690
 applied anatomy of, 610
 periosteum, 17
 secretions, 1195
 Internodal segment, 39
 Interossei muscles of foot, 540
 of hand, 508
 Interosseous artery, common, 625
 dorsal, 625
 recurrent, 625
 volar, 625
 membrane, antibrachial, 377
 crural, 400
 nerve, dorsal or posterior, 906
 volar or anterior, 901
 Interparietal bone, 197
 Interpeduncular fossa, 803
 ganglion, 790
 Interphalangeal articulations, 387, 420
 Interpubic fibrocartilaginous lamina, 391
 Intersegmental neurons, 751
 septa, 69
 Intersigmoid fossa, 1008
 Interspinal ligaments, 352
 Interspinales muscles, 448
 Interstitial keratitis, 966
 lamellæ, 19
 Intertarsal articulations, 414
 Intertragic notch, 980
 Intertransversarii muscles, 448
 Intertransverse ligaments, 352
 Intertrochanteric crest, 312
 line, 312
 Intertubercular plane, 1084
 sulcus, 274
 Intervenous tubercle, 557
 Interventricular foramen, 803, 825
 Intervertebral fibrocartilages, 350
 applied anatomy of, 351
 structure of, 350
 foramina, 161
 veins, 695
 Intestinal glands, 1112
 lymphatic trunk, 711, 726
 villi, 1111
 Intestine, development of, 128
 surface markings of, 1237
 Intestine, large, 1314
 applied anatomy of, 1127

- Intestine, lymphatics of, 731
 structure of, 1122
 vessels and nerves of, 1123
 Intestine, small, 1105
 applied anatomy of, 1123
 lymphatics of, 731
 structure of, 1110
 vessels and nerves of, 1113
 Intestinum crassum, 1114
 tenue, 1105
 duodenum, 1106
 ileum, 1108
 jejunum, 1108
 mesenteriale, 1108
 Intracartilaginous ossification, 22
 Intra-epithelial plexus of cornea, 955
 Intrafusal fasciculi, 1007
 fibres, 1007
 Intra-jugular process, 196
 Intralobular veins, 703, 1139
 Intramembranous ossification, 21
 Intraparietal sulcus of Turner, 809
 Intrapulmonary bronchi, 1042
 Intrathyroid cartilage, 1017
 Intravenous infusion, 689
 Intrinsic muscles of tongue, 1068.
 Involucrum, 25
 Involuntary muscle, 32
 Iodothylin, 1197
 Iridial angle, 953
 Iris, 958
 applied anatomy of, 367
 structure of, 958
 vessels and nerves of, 959
 Irregular bones, 161
 Irritation of cervical sympathetic, 941
 Ischial spine, 301
 Ischiocapsular ligament, 305
 Ischiocavernosus muscle, in female, 476
 in male, 474
 Ischiorectal fossa, 472
 applied anatomy of, 472
 abscess of, 472
 Ischiur., 301
 body of, 301
 ramus, inferior, 302
 superior, 301
 spine of, 301
 tuberosity of, 302
 Island of Reil, 811
 Islands, blood, 109
 Islets, interalveolar, of pancreas, 1132
 Isthmus, aortic, 121, 573
 of auditory tube, 988
 of external acoustic meatus, 982
 faucium, 1072
 of limbic lobe, 811
 rhombencephali, 91, 761
 of thyroid gland, 1195
 of uterine tube, 1182
 of uterus, 1184
 Iter chordæ arteriæ, 985, 992
 posterius, 985, 992
 Ivory or dentine, 1058
 Jacobson, nerve of, 876, 991
 vomeronasal cartilage of, 222, 947
 organs of, 82, 947
 Jejunal arteries, 636
 Jejunum, 1108
 lymphatic vessels of, 731
 Jelly of Wharton, 12, 62
 Joints. *See* Articulations.
 Jugal point, 261
 Jugular arch, venous, 675
 foramen, 244, 255
 fossa, 208, 209
 ganglion, of glossopharyngeal nerve, 875
 of vagus nerve, 878
 lymphatic trunks, 711, 712
 nerve, 932
 notch, 182, 196
 process, 196, 244
 surface, of temporal bone, 208
 vein, anterior, 675
 external, 675
 applied anatomy of, 675
 internal, 675
 applied anatomy of, 677
 bulbs of, 675, 676
 posterior external, 675
 Jugum, sphenoidale, 203
 Junctional tubule, 1148
 Karyokinesis, 2
 Karyomitome, 2
 Karyomitosis, 2
 Karyoplasm, 2
 Kataphase, 3
 Keratin, 7, 1010
 Keratitis, interstitial, 966
 Keratohyalin, 6, 1010
 Kerkkring, ossific centre of, 197
 Kidneys, 1143
 applied anatomy of, 1150
 blood-vessels of, 1149
 calyces of, 1145
 capsule of Bowman, 1147
 cortical substance of, 1147
 development of, 152
 fixating, 1151
 general structure of, 1147
 glomeruli, 1147
 horseshoe-shaped, 1151
 lymphatic vessels of, 732
 Malpighian bodies of, 1147
 medullary substance of, 1147
 minute anatomy of, 1147
 movable, 1151
 nerves of, 1150
 paranephric body, 1147
 relations of, 1143
 renal artery, 640, 1149
 fascia, 1146
 pelvis, 1146
 pyramids, 1147
 sinus, 1145
 tubules, 1147
 surface marking of, 1240
 veins of, 703, 1150
 Klumpke's paralysis, 906
 Knee-joint, 399
 applied anatomy of, 408
 bursæ of, 405
 movements of, 406
 surface anatomy of, 1257, 1260
 Knobs, basal, of Engelmann, 5
 Knock-knee, 408
 Knot, Hensen's, 50
 Krause, end-bulbs of, 1005
 membrane of, 31
 Kupffer, stellate cells of, 1139
 Kyphosis, 181
 Labbé, posterior anastomotic vein of, 679
 Labia cerebri, 814
 majora, 1191
 minora, 1191
 frenulum or fourchette of, 1192
 oris, 1046
 Labial artery, inferior, 584
 superior, 584
 commissures, 1191
 glands, 1046
 groove, primary, 129
 secondary, 129
 nerves, inferior, 926
 superior, 858
 Labiodental lamina, 1060
 Labrum, glenoidal, of shoulder-joint, 370
 of hip-joint, 396
 Labyrinth, membranous, 996
 osseous, 993
 development of, 106
 vessels of, 1004
 of ethmoidal bone, 218
 Lacertus fibrosus, 489
 Lacinate ligament, 535
 Lacrimal apparatus, 976
 applied anatomy of, 979
 development of, 106
 artery, 597
 bone, 220
 lesser, 221
 ossification of, 221
 caruncle, 976
 crest, anterior, 227
 posterior, 220
 ducts or canals, 977
 ampullæ of, 977
 fossa, 215, 227
 gland, 976
 structure of, 976
 groove, 221
 hamulus, 221
 nerve, 855
 notch, 225
 papillæ, 977
 process of inferior nasal concha, 220
 puncta, 977
 sac, 977
 structure of, 978
 tubercle, 228
 Lacteals, 707, 731, 1111
 Lactiferous ducts, 1193
 Lacuna magna of urethra, 1162
 Lacunæ of bone, 19, 20
 of urethra, 1162
 venous of dura mater, 680
 Lacunar ligament, 480
 Lacus lacrimalis, 974, 976
 Lagena, 999
 Lambda, 212, 261
 Lambdoidal suture, 195, 212, 241, 248
 Lamella, articular, of bone, 342
 Lamellæ of bone, 19
 circumferential, 19
 interstitial, 19
 primary, 19
 secondary, 19
 Lamellar cells, 9
 Lamina affixa, 823
 alar or dorsal, 87
 anterior elastic, of cornea, 954
 basal or ventral, 87
 basalis, 957

- Lamina choriocapillaris**, 956
cribrosa, of ethmoidal bone, 217
cribrosa sclera, 952
of cricoid cartilage, 1018
dental, 1060
dorsal or alar, 87
interpubic fibrocartilaginous, 391
labiodental, 1060
lingual, 1060
osseous spiral, of cochlea, 995
papyracea, of ethmoidal bone, 218
perpendicularis, of ethmoidal bone, 218
posterior elastic, of cornea, 954
reticular, 1003
secondary spiral, 996
suprachorioides, 952, 955
terminalis, 94, 800, 802
vasculosa, 956
ventral or basal, 87
- Laminae**, nasal, 80
of cerebral cortex, 829
of lentiform nucleus, 820
medullary, of thalamus, 795
of thyroid cartilage, 1017
of vertebrae, 162
- Laminectomy**, 182
- Langhans**, layer of, 50, 65
- Langley's ganglion**, 1053
- Lanternmann**, segments of, 39
- Large intestine**, 1114
caecum, 1114
appendix or vermiform process of, 1116
colic valve, 1115
colon, 1117
ascending, 1117
descending, 1118
iliac, 1119*
sigmoid or pelvic, 1119
transverse, 1118
rectum, 1120
anal canal, or pars analis recti, 1121
- Laryngeal artery**, inferior, 610
superior, 581
nerve, recurrent, 880
superior, 879
external branch, 880
internal branch, 880
part of pharynx, 1077
prominence, 1017
sacculæ, 1023
- Laryngopharyngeal nerves**, 932
- Laryngotomy**, 1030
- Laryngotracheal groove**, 142
tube, 142
- Larynx**, 1016
actions of muscles of, 1028
applied anatomy of, 1030
cartilages of, 1016
conus elasticus of, 1021
development of, 142
elastic membrane of, 1020
entrance to, 1023
glands of, 1027
inferior of, 1022
ligaments of, 1019
lymphatic vessels of, 718, 1027
mucous membrane of, 1027
muscles of, 1025
rima glottidis of, 1024
surface marking of, 1212
- Larynx**, ventricle of, 1023
ventricular folds of, 1023
vessels and nerves of, 1027
vestibule of, 1022
vocal folds of, 1023
- Lateral curvature of vertebral column**, 179, 191
parts of occipital bone, 195
mass of ethmoidal bone, 218
mesoderm, 52
segmental arteries, 121
sinuses, 681
ventricles, 815
- Latissimus dorsi muscle**, 478
- Lawn-tennis arm**, 492
leg, 535
- Layer**, ependymal, 86
of Langhans, 50, 65
granular, of Tomes, 1059
limiting or boundary of decidua, 64
mantle, 86
marginal, 86
of rods and cones, 963
scleratogenous, 69
- Lead poisoning**, 1048
- Left atrioventricular orifice**, 561
- Left vena cava**, ligament of, 552
- Leg**, fascia of, 528
deep transverse, 528
muscles of, 528
- Lemniscus or fillet**, 767, 771, 790
decussation of, 767
lateral, 790
medial, 791
- Length of face**, 261
of skull, 261
- Lens**, crystalline, 965
applied anatomy of, 968
axis of, 965
capsule of, 965
changes produced in, by age, 966
development of, 102
equator of, 965
poles of, 965
structure of, 965
suspensory ligament of, 965
vascular capsule of, 104
vesicle, 102
- Lenticular nucleus**, 819
glands of stomach, 1104
process of incus, 989
- Lentiform nucleus**, 819
- Lesser cavernous nerve**, 940
cornua of hyoid bone, 241
curvature of stomach, 1099
internal cutaneous nerve, 901
lacrimal bone, 221
multangular bone, 292
omentum, 1094
pelvis, 305
sac, or omental bursa, of peritoneum, 1088, 1091
boundaries of, 1091
sciatic foramen, 390
notch, 301
trochanter, 312
tubercle of humerus, 274
- Leucocytes**, 28
- Levator anguli oris muscle**, 430
ani, 409
glandulae thyroideae, 1196
menti, 430
palati, 1074
palpebrae superioris, 968
- Levator prostatae**, 470
scapula, 480
veli palatini, 1074
- Levatores costarum**, 451
prostatae, 470, 1176
- Lieberkühn**, crypts of, 1112
- Lien**, 1200
- Lienal artery**, 635
applied anatomy of, 635
plexus of nerves, 939
recess, 1092
vein, 705
- Lienorenal ligament**, 1091
- Ligament or Ligaments**—
accessory volar, 387
acromioclavicular, 367
alar, 358
of ankle, 411
annular, of ankle, 535
of proximal radio-ulna joint, 376
of wrist, anterior, 500
posterior, 503
anterior, of head of fibula, 409
of lateral malleolus, 410
anterior longitudinal, 349
antibrachial interosseous membrane, 379
arcuate, of diaphragm, 452
popliteal, 402
retinaculum of, 402
pubic, 390
articular disc, of sterno-clavicular joint, 366
of acromioclavicular joint, 367
of distal radio-ulnar joint, 378
atlanto-occipital membrane, anterior, 357
posterior, 357
of auditory ossicles, 990
of auricula or pinna, 981
bifurcated, 416
calcaneocuboid part of, 416
calcaneonavicular part of, 416
broad, of uterus, 1087, 1186
calcaneocuboid, dorsal, 415
plantar, 416
calcaneofibular, 412
calcaneotibial, 412
calcaneonavicular, plantar, 416
caroticooclinoid, 203
carpometacarpal, dorsal, 385
interosseous, 385
volar, 385
of carpus, 382, 383
central, of medulla spinalis, 846
check, 358
of eye, 972
collateral of carpus, 383
of elbow-joint, 374, 376
of inter-phalangeal joints of hand, 387
of foot, 420
of knee-joint, 402, 403
of metacarpophalangeal joints, 387
of metatarsophalangeal joints, 420
of wrist-joint, 381
conoid, 385
of Cooper, 460

Ligament or Ligaments (cont.)

coracoclavicular, 368
 coracohumeral, 370
 coronary, of knee, 405
 of liver, 1086, 1087, 1137
 costoclavicular, 366
 costocoracoid, 483
 costotransverse, 360
 costoxiphoid, 362
 cotyloid, 373
 crico-arytænid, posterior, 1021
 cricotracheal, 1020
 cricothyroid, middle, 1021
 cruciate, of atlas, 355
 crural, 535
 of knee, 403
 cuboideonavicular, 417
 cuneocuboid, 417
 cuneonavicular, 417
 deep, of tarsus, 416
 deltoid, 411
 denticulate, 846
 digital vaginal, 493
 dorsal carpal, 503
 radiocarpal, 381
 of elbow, 373
 radial collateral, 376
 ulnar collateral, 374
 of epididymis, 1165
 falciform, of liver, 1086
 fibrocartilaginous disc of sacrococcygeal symphysis, 352
 fibular collateral, of knee-joint, 403
 short, 402
 fundiform, of penis, 458, 1174
 gastrocolic, 1087
 gastrolenal, 1091, 1201
 gastropancreatic, 1093
 gastrophrenic, 1100
 Gimbernat's, 460
 glenohumeral, 369
 glenoid, of Cruveilhier, 387, 420
 of shoulder-joint, 370
 glenoidal labrum, of hip-joint, 396
 of shoulder-joint, 370
 hepatoduodenal, 1087, 1094, 1137
 hepatogastric, 1087, 1094, 1137
 hepatorenal, 1087, 1137
 of Hesselbach, 463
 of hip-joint, 393
 hyo-epiglottic, 1019
 hyothyroid, 1020
 iliofemoral, 395
 iliohumeral, 389
 iliothrochanteric, 395
 of inus, 990
 inferior transverse, of ankle-joint, 410
 of scapula, 369
 intermetacarpal, 386
 infundibulopelvic, 1186
 inguinal, 459
 reflected, 460
 interarticular, of ribs, 359
 sternocostal, 362
 intercarpal, 382, 383
 interchondral, 363
 interclavicular, 366
 interclinoid, 203

Ligament or Ligaments (cont.)

intercuneiform, 417
 interfoveolar, 463
 intermetatarsal, 418
 interphalangeal, 387, 420
 interpubic fibrocartilaginous lamina, 391
 interspinal, 352
 intertarsal, 414
 intertransverse, 352
 intervertebral fibrocartilages, 350
 ischiocapsular, 395
 of knee-joint, 400
 laciniate, 535
 lacunar, 460
 of larynx, 1019
 lateral, of uterus, 1087, 1180
 left triangular, of liver, 1137
 of left vena cava, 126, 552, 672
 lienorenal, 1091
 of liver, 1137
 long plantar, 416
 of Mackenrodt, 1187
 of malleus, 990
 lumbocostal, 360
 medial palpebral, 429
 membrana tectoria, 358
 sterna, 361
 menisci of knee-joint, 404
 metacarpophalangeal, 386
 accessory volar, 387
 collateral, 387
 metatarsophalangeal, 420
 accessory plantar, 420
 collateral, 420
 middle cricothyroid, 1021
 middle umbilical, 1157
 mucosum, of knee, 401
 of neck of rib, 360
 nuchæ, 352
 oblique cord, 377
 popliteal, 402
 occipito-axial, 358
 orbicular, 376
 of ovary, 1170
 pectinate, of iris, 955
 phrenicocolic, 1096, 1118
 phrenicolenal, 1091, 1201
 phrenicopericardiac, right, 702
 of pinna or auricula, 981
 pisohamate, 382
 pisometacarpal, 382
 plantar, long, 416
 posterior crico-arytænid, 1021
 of head of fibula, 409
 of knee, 402
 of lateral malleolus, 410
 longitudinal, 349
 Poupart's, 459
 pterygospinous, 203, 435
 pubic, arcuate, 390
 superior, 390
 pubocapsular, 395
 pulmonary, 1033
 quadrate, 376
 radial collateral, of elbow-joint, 376
 of wrist-joint, 382
 radiate, 359
 sternocostal, 361
 radiocarpal, 380
 of radio-ulnar joints, 376
 reflected inguinal, 460
 retinacula, of hip-joint, 394
 of patella, 400

Ligament or Ligaments (cont.)

retinaculum, of arcuate popliteal ligament, 402
 rhomboid, 366
 right triangular, of liver, 1137
 round, of liver, 1127
 of uterus, 1186
 sacrococcygeal, 352
 sacro-iliac, anterior, 388
 interosseous, 399
 posterior, 388
 long, 388
 short, 388
 sacrosciatic, great, 389
 small, 390
 sacrospinous, 390
 sacrotuberous, 389
 falciform process of, 389
 of scapula, 368
 semilunar fibro-cartilages of knee-joint, 404
 of shoulder-joint, 369
 sphenomandibular, 347
 spinoglenoid, 369
 spring, 417
 stellate, 359
 sternoclavicular, 366
 sternopericardiac, 551
 structure of, 342
 stylohyoid, 441
 stylomandibular, 347, 435
 subpubic, 390
 superior transverse, of scapula, 368
 suprascapular, 368
 supraspinal, 352
 suspensory, of axilla, 481
 of eye, 972
 of lens, 965
 of mamma, 481
 of ovary, 1179
 of penis, 1174
 sutural, 342
 talocalcaneal, anterior, 414
 interosseous, 414
 lateral, 414
 medial, 414
 posterior, 414
 talonavicular, 415
 talofibular, anterior, 412
 posterior, 412
 talotibial, anterior, 412
 posterior, 412
 tarsometatarsal, 418
 of tarsus, 414
 temporomandibular, 347
 teres, of hip-joint, 395
 of liver, 569, 705, 1086, 1137
 thyreo-epiglottic, 1018, 1022
 tibial collateral, of knee-joint, 402
 tibiofibular, 409, 410
 tibionavicular, 412
 transversale colli uteri, 1187
 transverse acetabular, 396
 of atlas, 355
 crus inferius, 355
 superius, 355
 carpal, 500
 crural, 535
 humeral, 370
 inferior, 410
 of scapula, 369
 of knee, 405
 transverse metacarpal, 386
 metatarsal, 418
 superior, of scapula, 368

Ligament or Ligaments (cont.)
 trapezoid, 367
 triangular, of liver, 1087
 of urethra, 475, 476
 of tubercle of rib, 360
 ulnar collateral, of elbow-joint, 370
 of wrist-joint, 381
 umbilical, lateral, 644
 middle, 1157
 of urinary bladder, 1157
 uterosacral, 1186
 of uterus, 1186
 ventricular, of larynx, 1023
 of vertebral arches, 351
 bodies, 348
 vocal, 1023
 • volar carpal, 500
 of white fibrous tissue, 342
 of Wrisberg, 404
 of wrist-joint, 381
 Y-shaped, of Bigelow, 395, 398
 of yellow elastic tissue, 342
 of Zinn, 970
 zona orbicularis of hip-joint, 394
Ligamenta flava, 351
 suspensoria of mamma, 481
Ligamentous action of muscles, 345
 applied anatomy of, 346
Ligamentum annulare baseos
 stapedis, 990
 apicis dentis, 358
 arteriosum, 568
 carpi radiatum, 383
 conjugale, 359
 cruciatum atlantis, 355
 denticulatum, 846
 mucosum, 401
 nuchæ, 352
 patellæ, 402
 terci femoris, 395
 hepatis, 569, 705, 1086, 1137
 transversale colli uteri, 1187
 venosum, 569, 705, 1137
Ligature of abdominal aorta, 632
 axillary artery, 614
 brachial artery, 618
 carotid artery, common, 578
 external, 579
 internal, 596
 dorsalis pedis artery, 666
 femoral artery, 656
 gluteal arteries, 651
 hypogastric artery, 644
 iliac artery, common, 643
 external, 651
 internal, 644
 innominate artery, 575
 jugular vein, internal, 677
 lingual artery, 582
 popliteal artery, 661
 radial artery, 622
 subclavian artery, 604
 tibial artery, anterior, 665
 posterior, 667
 ulnar artery, 624
Ligula, 785
Limbic lobe, 811
Limb, development of, 82
Limbus fossæ ovalis, 557
 laminae spirales, 1001
Linæa nasi, 945

Limiting or boundary layer of
 decidua, 64
 membranes of retina, 963, 964
Line or Lines—
 arcuate, of ilium, 298
 contour, of Owen, 1059
 curved, of ilium, 298, 299
 Dobie's, 31
 Frommann's, 39
 gluteal, of ilium, 298, 299
 of Hensen, 31
 intercondyloid, 314
 intertrochanteric, 312
 mylohyoid, 235
 Nélaton's, 1260
 mucal, highest, 193
 inferior, 193
 median, 193
 superior, 193
 oblique, of fibula, 323
 of mandible, 235
 of radius, 282
 of thyroid cartilage, 1017
 pectineal, 312
 perpendicular, of ulna, 285
 popliteal, of tibia, 320
 of Schreger, 1059
 temporal, 203, 211, 214
 white, of pelvic fascia, 468
Linea alba, 464
 aspera, 312
 nuchæ suprema, 193
 quadrata, 312
 semicircularis, 464
 splendens, 846
 terminalis, 305
Lineæ semilunares, 465
Lingua, 1064
Lingual artery, 581
 applied anatomy of, 582
 branches of glossopharyngeal nerve, 876
 gyrus, 809
 lamina, 1060
 lymph-glands, 714
 nerve, 862
 tonsil, 1065, 1072
 veins, 677
Linguiform lobe of liver, 1142
Lingula of cerebellum, 776
 mandibulæ, 236
 of sphenoid, 198
Linin, 2
Lip, rhombic, 92
 tympanic, 1001
 vestibular, 1001
Lips, 1046
Liquor amnii, 62
 folliculi, 1181
 sanguinis, 26
Lissauer, fasciculus of, 756
Littre, urethral glands of, 1162
Liver, 1133
 applied anatomy of, 1142
 bare area of, 1136
 bile ducts of, 1140
 common bile-duct, 1141
 cystic duct, 1141
 development of, 139
 excretory apparatus of, 1140
 fossæ of, 1134
 gall-bladder, 1140
 hepatic artery, 633, 1137
 duct, 1140
 veins, 703, 1138
 ligaments of, 1137
 lobes of, 1135

Liver, lobules of, 1130
 lymphatic vessels of, 731
 portal vein, 704, 1137
 structure of, 1138
 surface markings of, 1238
 surfaces of, 1136
 vessels and nerves of, 1137
Lobes of cerebellum, 775
 of cerebral hemisphere, 807
 frontal, 808
 insula, 811
 limbic, 811
 occipital, 809
 olfactory, 812
 parietal, 808
 præcuneus, 809
 quadrato, 809
 temporal, 810
 of liver, 1135
 caudate, 1135
 left, 1135
 quadrato, 1135
 Riedel's, 1142
 right, 1135
 Spigelian, 1135
 of lungs, 1040
 of thymus, 1198
 of thyroid gland, 1195
Lobular bronchioles, 1042
Lobule of auricula, 980
 paracentral, 808
 parietal, inferior, 809
 superior, 809
Lobules of epididymis, 1167
 of liver, 1139
Lobuli testis, 1166
Lobulus centralis, 776
Lobus clivi, 777
 culminis, 777
 noduli, 778
 pyramidalis, 778
 semilunaris, 777
 tuberis, 778
 uvula, 778
Lockwood, superior tendon of, 970
Locomotor ataxy, 838
Locus caeruleus, 767, 786
Long bones, 160
 bifurcal nerve, 860
 ciliary nerves, 855
 or internal saphenous nerve, 916
 plantar ligament, 416
 root of ciliary ganglion, 855
 subscapular nerve, 899
 thoracic artery, 615
 nerve, 897
Longissimus capitis muscle, 447
 cervicis muscle, 447
 dorsi muscle, 447
Longitudinal arc of skull, 261
 fasciculus, inferior, 820
 medial or posterior, 771, 791
 superior, 828
 cerebral fissure, 806
 ligament, anterior, 340
 posterior, 349
 sinus, inferior, 681
 superior, 680
 stris, lateral and medial, 813
 sulci of heart, 553
Longitudinalis lingus inferior, 1069
 superior, 1069
Longus colli muscle, 442
 capitis muscle, 442

Loop of Henle, 1148
 Loose cartilage of knee-joint, 408
 Lordosis, 181
 Löwenthal, cerebellospinal tract of, 755
 Lower extremity, arteries of, 653
 articulations of, 387
 bones of, 298
 lymph-glands of, 721
 lymphatic vessels of, 723
 muscles of, 513
 surface anatomy of, 1254
 markings of, 1259
 veins of, 695
 Lower, tubercle of, 557
 Lumbar arteries, 642
 abscess, 515
 curve of vertebral column, 179
 enlargement of medulla spinalis, 746
 lymph-glands, 726
 lymphatic trunks, 711
 nerves, anterior divisions of, 911
 posterior divisions of, 890
 plexus, 911
 applied anatomy of, 927
 puncture, 844
 regions of abdomen, 1084
 triangle, 480
 vein, ascending, 702
 veins, 702
 vertebra, 169, 178
 Lumbocostal arch, lateral, 452
 medial, 452
 ligament, 360
 Lumbodorsal fascia, 444
 Lumbo-inguinal nerve, 913
 Lumbosacral trunk, 911
 Lumbricales muscles, of foot, 539
 of hand, 508
 Lunate bone, 291
 ossification of, 296
 sulcus, 809*
 surface of acetabulum, 303
 Lung-buds, 142
 Lungs, 1037
 applied anatomy of, 1043
 development of, 142
 fissures and lobes of, 1040
 lymphatic vessels of, 738
 root of, 1041
 structure of, 1041
 surface markings of, 1231
 vessels and nerves of, 1042
 Lunulae of nails, 1011
 of semilunar valves, 559, 561
 Luteal cells, 1181
 Lutz, nucleus of, 799
 Lymph, 29
 capillaries, 29
 path or sinus, 708
 sacs, 127
 Lymph-gland or glands, 708
 applied anatomy of, 710
 of abdomen, 724
 parietal, 724
 visceral, 726
 aortic, 726
 auricular, anterior, 714
 posterior, 714
 axillary, 719
 applied anatomy of, 720

Lymph-gland or glands (*cont.*)
 bronchial, 737
 broncho-pulmonary, 737
 buccinator, 714
 cervical, anterior, 715
 deep, 715
 applied anatomy of, 718
 superficial, 715
 of Cloquet, 723
 cystic, 727
 deltoideopectoral, 718
 diaphragmatic, 736
 epigastric, inferior, 725
 facial, 714
 deep, 714
 gastric, inferior, 727
 superior, 726
 germ centres of, 709
 of head, 713
 hepatic, 727
 hypogastric, 725
 ileocolic, 728
 iliac, circumflex, 725
 common, 725
 external, 725
 infrahyoid, 715
 infraorbital, 714
 inguinal, 722
 applied anatomy of, 723
 intercostal, 735
 lingual, 714
 of lower extremity, 721
 lumbar, 726
 mammary, internal, 735
 mediastinal, anterior, 736
 posterior, 736
 mesenteric, inferior, 729
 superior, 728
 mesocolic, 728
 of neck, 714
 obturator, 725
 occipital, 713
 pancreaticoduodenal, 731
 pancreaticolienal, 727
 paracardial, 727
 pararectal, 729
 paratracheal, 715
 parietal of abdomen and pelvis, 724
 of thorax, 735
 parotid, 714
 of pelvis, 724
 popliteal, 721
 applied anatomy of, 723
 pre-aortic, 726
 prelaryngeal, 715
 pretracheal, 715
 principal lymph-glands of tongue, 718
 pulmonary, 737
 retropharyngeal, 714
 of Rosenmüller, 723
 sacral, 725
 Stahr, middle lymph-gland of, 714
 sternal, 735
 structure of, 708
 submaxillary, 714
 submental, 714
 subpyloric, 727
 suprahyoid, 714
 supramandibular, 714
 supratrochlear, 718
 of thorax, 735
 parietal, 735
 visceral, 736
 tibial, anterior, 721

Lymph-gland or glands (*cont.*)
 tracheal, 737
 tracheobronchial, 736
 applied anatomy of, 737
 of upper extremity, 718
 deep, 719
 superficial, 718
 visceral, of abdomen and pelvis, 726
 of thorax, 736
 Lymphatic duct, right, 712
 nodules, aggregated, 1113
 solitary, 1112, 1123
 system, 707
 development of, 127
 trunk, bronchomediastinal,
 left, 712, 737
 right, 712, 737
 intestinal, 711, 726
 jugular, left, 711
 right, 712
 lumbar, 711
 subclavian, left, 712
 right, 712
 Lymphatic vessels, 707
 of abdomen and pelvis, 729
 parietal, 729
 visceral, 730
 of abdominal viscera, 730
 of abdominal wall, 729
 afferent, 709
 of anal canal and anus, 731
 applied anatomy of, 710
 of auricle and external acoustic meatus, 716
 bronchomediastinal trunks, 712
 of cæcum, 731
 chyliferous vessels or lacteals, 707
 cisterna chyli, 711
 of colon, 731
 of common bile-duct, 732
 deep, 710
 development of, 127
 of diaphragm, 738
 of ductus deferens, 735
 of duodenum, 731
 efferent, 709
 of external genitals, 730
 of face, 716
 of gall-bladder, 732
 of head and neck, 716
 of heart, 738
 of ileum, 731
 intestinal trunk, 711
 of jejunum, 731
 jugular trunks, 711, 712
 of kidney, 732
 lacteals or chyliferous vessels, 707
 of larynx, 718
 of liver, 731
 of lower extremity, 723
 lumbar trunks, 711
 of lungs, 738
 of mamma, 738
 of mouth, 717
 of nasal cavities, 717
 of neck, 718
 of oesophagus, 739
 of ovary, 735
 of palatine tonsil, 717
 of pancreas, 732
 of pelvis, 729
 of perineum, 730
 of pharynx, 718

Lymphatic vessels, of pleura, 739
of prostate, 734
pulmonary, 737
of rectum, 731
of reproductive organs, 734
right lymphatic duct, 712
of scalp, 716
of spleen, 732
of stomach, 730
structure of, 707
subclavian trunks, 712, 720
superficial, 709
of suprarenal gland, 732
of testis, 734
thoracic duct, 710
applied anatomy of, 712
of thoracic viscera, 738
wall, 737
of thymus, 739
of thyroid gland, 718
of tongue, 718
of upper extremity, 721
of ureter, 733
of urethra, 734
of urinary bladder, 733
of urinary organs, 732
of uterine tube, 735
of uterus, 735
of vagina, 735
of vermiform process, 731
of vesiculæ seminales, 735
Lymphocyte, 29
Lymphoid tissue, 12
Lyra of fornix, 824
Macewen, suprameatal triangle of, 203
Mackenrodt, ligament of, 1187
Macula acustica sacculi, 997
utricle, 997
cribrosa media, 993
superior, 994
lutea, 961
structure of, 964
Magma réticulé, 50
Majendie, foramen of, 785, 843
Malar bone, 233
Male genital organs, 1104
bulbo-urethral glands, 153, 1178
ductus deferens, 1168
ejaculatory ducts, 1170
epididymis, 1164
penis, 1173
prostate, 1176
spermatic cord, 1170
testes, 1164
vesiculæ seminales, 1169
proneucleus, 48
urethra, 1160
Malleolar arteries, 665, 668
folds, anterior and posterior, 985
sulcus, 321
Malleolus, lateral, 324
medial, 321
Malleus, 989
cog-tooth or spur of, 989
development of, 108
head, 989
ligament of, 990
manubrium, 989
neck, 989
process, anterior, 989
lateral, 989
processus brevis, 989
gracilis, 989

Malpighian bodies of kidney, 1147
of spleen, 1203
Mamillary processes of vertebrae, 170
Mamma, 1192
applied anatomy of, 1194
development of, 85
lymphatic vessels of, 738
papilla or nipple of, 1193
suspensory ligaments of, 481
structure of, 1193
vessels and nerves of, 1194
Mammary artery, internal, 609
applied anatomy of, 610
external, 616
lymph-glands, internal, 735
papilla or nipple, 1193
veins, internal, 691
Mandible, 235
alveolar part of, 236
angle of, 236
articulation of, 346
body of, 235
changes in, due to age, 238
condyloid process of, 237
coronoid process of, 237
ossification of, 237
ramus of, 236
Mandibula, 235
Mandibular arch, 77
branch of facial nerve, 871
canal, 236
foramen, 236
fossa, 203, 243, 246
nerve, 860
notch, 237
symphysis, 235
Mantle layer, 86
Manubrium mallei, 989
of sternum, 182
Margin, supraorbital, 214
Marginal layer, 86
gyrus, 808
sinus of placenta, 67
veins of foot, 695
Margins of heart, 554, 555
supraorbital, 214
Marrow, red, 18, 28
yellow, 18
Marshall, oblique vein of, 126, 552, 672
vestigial fold of, 126, 552, 672
Martinotti, cells of, 831
Massa intermedia, 794, 803
Masses, lateral of atlas, 165
lateral, of ethmoidal bone, 218
Masseter muscle, 432
Masseteric artery, 589
nerve, 860
Mastoid air-cells, 205, 987
antrum, 206, 986
branch of occipital artery, 585
canaliculus, 208, 244
emissary vein, 686
foramen, 205
notch, 205
portion of temporal bone, 205
process, 205
Maternal portion of placenta, 66
Matrix of areolar tissue, 7
dental, 1059
of nail, 1011
Maturation of ovum, 43
Mature ovum, 43

Maxilla, 224
alveolar process of, 228
antrum of Highmore, 226, 950
body of, 224
changes in, due to age, 230
frontal process of, 227
ossification of, 229
palatine process of, 228
sinus of, 226, 950
zygomatic process of, 227
Maxillary artery, external, 582
applied anatomy of, 584
peculiarities of, 584
internal, 587
nerve, 866
inferior, 860
process of inferior nasal concha, 220
of fœtus, 78, 80
of palatine bone, 232
sinus, 226, 950
applied anatomy of, 227
surface anatomy of, 1216
tuberosity, 224
vein, internal, 674
Meatal plate, 108
Meatus, external acoustic, 209, 246, 981
applied anatomy of, 983
internal, 207, 255
primary, 108
secondary, 108
Meatuses of the nose, 219, 220, 257, 945, 946
Mechanism of pelvis, 391
of respiration, 456
of thorax, 363
Meckel's cartilages, 77, 237
diverticulum, 57
ganglion, 858
Media, refracting of bulb of eye, 964
Medial geniculate body, 796
longitudinal fasciculus, 771, 791
wall of nasal cavity, 256, 946
Median antibrachial vein, 689
basilic vein, 687
cubital vein, 687
nerve, 901
applied anatomy of, 907
Mediastinal arteries, from aorta, 629
from internal mammary, 609
cavity, 1035
applied anatomy of, 1036
anterior, 1035
middle, 1036
posterior, 1036
superior, 1035
lymph-glands, anterior, 737
posterior, 737
pleura, 1033
Mediastinum testis, 1165
Medulla of hair, 1014
Medulla oblongata, 761
anterior region of, 762
applied anatomy of, 772
arcuate fibres of, 769
development of, 91
fasciculus cuneatus of, 766
gracilis of, 766
fissures and sulci of, 762
formatio reticularis of, 771
grey substance of, 768

Medulla oblongata, lateral
 region of, 763
 olive of, 763
 posterior region of, 763
 pyramid of, 762
 pyramidal decussation, 762
 restiform bodies of, 769
 sensory decussation, 767
 structure of, 765
ossium flava, 18
rubra, 18, 28
spinalis, 745
 applied anatomy of, 750
 central canal of, 750
 columns of, 749
 cornua of, 749
 development of, 86
 distribution of nerve-cells
 in, 751
 enlargements of, 746
 fasciculi of, 755
 fissure of, 747
 funiculi of, 754
 grey commissures of, 750
 substance of, 748
 internal structure of, 748
 ligamentum denticulatum
 of, 846
 meninges of, 839
 applied anatomy of,
 844
 nerve fasciculi of, 754
 sulci of, 747
 veins of, 695
 white commissure of, 747
 substance of, 753
Medullary arteries, 608
 cavity, 100
 laminae of lentiform nucleus,
 820
 of thalamus, 795
 membrane of bone, 17
 portion of suprarenal gland,
 1206
 rays of kidney, 1147
 segments of nerves, 39
 sheath of nerve-fibres, 39
 spaces of bone, 23
 substance of kidney, 1147
 velum, anterior, 780, 784
 posterior, 777, 780, 784
Medullated nerve-fibres, 37
Mesencephalic skulls, 260
Megakaryocytes, 28
Meibomian glands, 975
Meissner's plexus, 1114
 tactile corpuscles, 975
Melanin, 13
Membrana granulosa of
 Graafian follicle, 1180
limitans externa, 964
interna, 963
pupillaris, 105, 960
sterni, 361
tectoria, 358
Membrane, accessory tectorial,
 1004
 antibrachial interosseous,
 377
 arachnoid, 842
 atlanto-occipital, anterior,
 357
 posterior, 357
 basilar, 996, 1001
 bucconasal, 80
 buccopharyngeal, 51
 cloacal, 51, 139
 costocoracoid, 483

Membrane, cricothyroid, 1021
 crural interosseous, 409
 elastic, of larynx, 1020
 fenestrated, 11
 hyaloid, 965
 hyothyroid, 1020
 hypoglossal, 1070
 interosseous, antibrachial,
 377
 crural, 409
 of Krause, 31
 medullary, of bone, 17
 of Nasmyth, 1062
 nuclear, 2
 obturator, 524
 pleuropericardial, 145
 pleuroperitoneal, 145
 pupillary, 105, 960
 of Reissner, 999
 secondary tympanic, 996
 of Shrapnell, 986
 tectorial, of ductus cochlearis,
 1003
 tympanic, 985
 structure of, 986
 vestibular, 999
 vitelline, 47
Membranes—
 basement, 12
 of brain and medulla spinalis,
 839
 closing, 77
 foetal, 59
 intercostal, 450
Membranous labyrinth, 996
 development of, 106
 portion of urethra, 1161
 vertebral column, 69
Menière's disease, 1005
Meningeal artery or arteries,
 accessory, 559
 anterior, 590, 538
 from ascending pharyn-
 geal, 581
 middle, 597
 applied anatomy of,
 589
 surface marking of, 1216
 from occipital, 585
 recurrent, from lacrimal,
 597
 from vertebral, 607
 branch of spinal nerve,
 887
 layer of dura mater, 839
 nerves from hypoglossal, 884
 from maxillary, 857
 from vagus, 879
 sinuses, middle, 686
 veins, middle, 686
Meninges of brain and medulla
spinalis, 839
Meningitis, 844
 acute spinal, 844
Meningocele, 262
Menisci, 16
 of knee-joint, 404
Meniscus, 344
Mental foramen, 235
 canals, 236
 nerve, 862
 point, 260
 protuberance, 235
 spines, 235
 tubercle, 235
Mentalis muscle, 430
Merkel's tactile discs of, 1005
Meroblastic ova, 48

Mesencephalic, 109
**Mesencephalic root of tri-
 geminal nerve**, 794
Mesencephalon, 53, 93, 787
Mesenteric artery, inferior, 638
 superior, 635
 ganglion, inferior, 940
 superior, 939
 lymph-glands, 728, 729
 part of small intestine, 1108
 plexuses of nerves, 939
 vein, inferior, 705
 superior, 705
Mesenteries, 1095
 mesentery proper, 1095
 posterior common, 135
 sigmoid mesocolon, 1096
 transverse mesocolon, 1095
**Mesenteriole of vermiform pro-
 cess**, 1095
Mesocardium, arterial, 551
 venous, 552
Mesocephalic skulls, 260
Mesocolic lymph-glands, 728
Mesocolon, foetal, 135
 sigmoid, 1096
 transverse, 1095
Mesoderm, 52
 formation of, 50
 lateral, 52
 paraxial, 52
 primitive, 50
 somatic, 52
 splanchnic, 53
Mesogastrium, dorsal, 135
 ventral, 134, 139
Mesognathion, 264
Mesonephros, 146
Mesorchium, 149
Mesosalphinx, 1186
Mesovarium, 149, 1180
Metacarpal bones, 294
 fifth, 296
 first, 294
 fourth, 295
 second, 295
 third, 295
 applied anatomy of, 298
 common characteristics of,
 294
 individual characteristics
 of, 294
 ossification of, 297
 ligament, transverse, 386
**Metacarpophalangeal articula-
 tions**, 386
Metacarpus, 294
Metanephros, 152
Metaphase of karyokinesis, 2
Metatarsal arteries, 666, 669
 bones, 335
 fifth, 337
 first, 336
 fourth, 337
 second, 337
 third, 337
 common characteristics of,
 335
 individual characteristics
 of, 336
 ossification of, 338
 ligament, transverse, 419
**Metatarsophalangeal articula-
 tions**, 420
Metatarsus, 335
Metathalamus, 94, 796
Metencephalon, 91, 761
Metopic suture, 213

Meynert, basal optic nucleus of, 800
 fasciculus retroflexus of, 797
 fountain decussation of, 792
 substantia innominata of, 822
 Microcephalic skulls, 260
 Microcytes, 26
 Mid-brain, 53, 93, 787
 Mid-carpal joint, 382
 Milk-ridge, 85
 Milk-teeth, 1067
 Miosis, 852
 Mitochondrial sheath, 45
 Mitosis, heterotypical, 3
 homotypical, 3
 Mitral cells, 834
 valve, 561
 Moderator band, 559
 Modiolus of cochlea, 996
 spiral canal of, 995
 Molar glands, 1046
 teeth, 1057
 Molecular layer of cortex of cerebellum, 781
 Monakow, rubrospinal tract of, 755
 Monaster, 2
 Monorchism, 1167
 Monro, foramen of, 803, 825
 sulcus of, 94, 803
 Mons pubis or Veneris, 1191
 Monticulus, 776
 Morbus coxae senilis, 399
 Morgagni, hydatid of, 149, 1165, 1182
 rectal columns of, 1121
 sinus of, 1078
 Morula, 49
 Moss-fibres, 782
 Motor area of cerebral cortex, 831
 decussation, 836
 end-plate, 743
 fibres of posterior nerve-roots, 750*
 nerves, 743
 neurons, lower and upper, 836
 paralysis, 838
 tract, 835
 Mouth cavity, 1046
 development of, 129
 lymphatic vessels of, 717
 mucous membrane of, 1046
 rima of, 1046
 vestibule of, 1046
 Movable articulations, 344
 kidney, 1151
 vertebrae, 161
 Movements of auditory ossicles, 990
 permitted in joints, 345
 angular, 345
 circumduction, 345
 gliding, 345
 rotation, 345
 Mucigen, 5
 Mucous glands of tongue, 1070
 sheaths of tendons around ankle, 536
 on back of wrist, 503
 on front of wrist, 501
 tissue, 12
 Müller, sustentacular fibres of, 963
 orbitalis muscle of, 971
 palpebral muscle of, 968, 971*

Müllerian ducts, 149
 eminence, 149
 Multangular bone, greater, 292
 ossification of, 296
 lesser, 292
 ossification of, 297
 Multifidus muscle, 448
 Muscle or muscles—
 of abdomen, 456
 abductor hallucis, 538
 digiti quinti (foot), 539
 (hand), 508
 indicis, 509
 pollicis brevis, 506
 longus, 499
 accessorius of back, 447
 of foot, 539
 adductor brevis, 520
 hallucis, 539
 longus, 520
 magnus, 521
 minimus, 521*
 pollicis, 506
 of anal region, 471
 anconeus, 498
 anterior crural, 528
 anterior femoral, 515
 anterior vertebral, 442
 antero-lateral of abdomen, 456
 of antero-lateral region of neck, 435
 antitragicus, 981
 aponeuroses of, 425
 applied anatomy of, 424
 of arm, 488
 arrectores pilorum, 1014
 articularis genus or sub-crureus, 519
 aryepiglotticus, 1026
 arytenoidens obliquus, 1026
 transversus, 1026
 of auricula or pinna, 981
 auricularis, anterior, 981
 posterior, 981
 superior, 981
 axillary arch, 480
 azygos uvulae, 1075
 biceps brachii, 489
 femoris, 526
 biventer cervicis, 448
 brachialis, 489
 brachialis anticus, 489
 brachioradialis, 496
 bronchial, 1042
 buccinator, 431
 bulbocavernosus, 473, 476
 caninus, 430
 cardiac, 33
 cervical, superficial and lateral, 437
 cervicalis ascendens, 447
 chondroglossus, 1068
 ciliaris, 957
 coccygeus, 471
 columna, 31
 complexus, 448
 compressor naris, 429
 connecting the upper extremity to the vertebral column, 478
 constrictor pharyngis inferior, 1078
 medius, 1078
 superior, 1078
 urethrae, 476
 coracobrachialis, 488
 corrugator, 429

Muscle or muscles (*cont.*)
 corrugator cutis ani, 472
 cremaster, 461
 cricoarytenoidens lateralis, 1025
 posterior, 1025
 cricothyroideus, 1025
 crureus, 519
 deep, of back, 444
 deltoideus, 485
 depressor septi, 429
 anguli oris, 430
 detrusor urinae, 1159
 development of, 34, 84
 diaphragm, 452
 digastricus, 439
 dilatator naris, anterior, 430
 posterior, 429
 pupillae, 959
 tubae, 988
 Dobie's line of, 31
 dorsal antibrachial, 496
 dorsal of foot, 537
 dorsoepitrochlearis brachii, 490
 ejaculator urinae, 473
 endomysium of, 30
 epioranialis, 426
 epimysium of, 30
 erector clitoridis, 476
 penis, 474
 spinae or sacrospinalis, 445
 extensor carpi radialis brevis, 496
 longus, 496
 ulnaris, 498
 coccygis, 448
 digiti quinti proprius, 497
 digitorum brevis, 537
 communis, 497
 longus, 528
 hallucis longus, 528
 indicis proprius, 500
 ossis metacarpi pollicis, 499
 pollicis brevis, 499
 longus, 499
 of eyelids, 428
 fasciculi of, 30
 of fauces, 1074
 fibres, development of, 34
 first plantar interosseous, 539
 first volar interosseous, 506
 fixation, 424
 flexor accessorius, 539
 carpi radialis, 492
 ulnaris, 492
 digiti quinti brevis, of foot, 540
 of hand, 508
 digitorum brevis, 538
 longus, 532
 profundus, 493
 sublimis, 493
 hallucis brevis, 539
 longus, 432
 pollicis brevis, 506
 longus, 494
 of foot, 537
 of forearm, 491
 form of, 423
 frontalis, 427
 gastrocnemius, 530
 gemellus inferior, 525
 superior, 525
 genioglossus, 1067
 geniohyoideus, 441
 glossopalatinus, 1075

Muscle or muscles (cont.)
 of gluteal region, 522
 gluteus maximus, 522
 medius, 522
 minimus, 522
 gracilis, 519
 of hand, 500
 of head, 426
 heliois major, 981
 minor, 981
 Hensen's line of, 31
 hyoglossus, 1067
 of iliac region, 513
 iliacus, 514
 iliococcygeus, 470
 iliocostalis cervicis, 447
 dorsi, 447
 lumborum, 447
 iliopsoas, 514*
 ilioacralis, 470
 incisivus labii inferioris, 432
 superioris, 432
 infrapinnatus, 487
 insertion of, 424
 intercostales, 450
 intermediate volar, 508
 interossei, of foot, 540
 of hand, 508
 interspinales, 448
 intertransversarii, 448
 involuntary, 32
 ischioavernosus, 474, 476
 Krause's membrane of, 31
 of larynx, 1025
 lateral crural, 534
 vertebral, 444
 volar, 506
 latissimus dorsi, 478
 of leg, 528
 levator anguli oris, 430
 ani, 469
 glandulae thyroideae, 1196
 menti, 430
 palpebrae superioris, 968
 prostate, 470, 1176
 scapulae, 480
 veli palatini (levator palati), 1074
 levatores costarum, 451
 ligamentous action of, 345
 longissimus capitis, 447
 cervicis, 447
 dorsi, 447
 longitudinalis linguae inferior, 1069
 superior, 1068
 longus capitis, 442
 colli, 442
 of lower extremity, 513
 lumbricales, of foot, 539
 of hand, 508
 masseter, 433
 of mastication, 432
 meaning of the terms
 "origin" and "insertion" of, 424
 medial femoral, 519
 volar, 508
 mentalis, 430
 of mouth, 430
 multifidus, 448
 mylohyoideus, 441
 nasalis, 429
 nasolabialis, 432
 of nose, 429
 obliquus auriculae, 981
 capitis inferior, 449
 superior, 449

Muscle or muscles (cont.)
 obliquus externus abdominis, 458
 internus abdominis, 460
 oculi inferior, 970
 superior, 970
 obturator externus, 525
 internus, 524
 occipitalis, 427
 occipitofrontalis, 426
 ocular, 968
 omohyoideus, 442
 opponens digiti quinti
 of foot, 540
 of hand, 508
 pollicis, 506
 orbicularis oculi, 428
 oris, 431
 orbitalis of Müller, 971
 origin of, 424
 of palate and fauces, 1074
 palatoglossus, 1075
 palatopharyngeus, 1075
 palmaris brevis, 508
 longus, 492
 palpebral, of Müller, 968, 971*
 pectineus, 520
 pectoralis major, 482
 minor, 483
 of pelvis, 467
 of perineum, 471
 peroneus brevis, 534
 longus, 534
 tertius, 529
 pharyngopalatinus, 1075
 of pharynx, 1077
 of pinna or auricula, 981
 piriformis, 523
 plain, 32
 plantar, first layer, 538
 fourth layer, 540
 second layer, 539
 third layer, 539
 plantaris, 531
 plate, 69
 platysma, 437
 popliteus, 531
 posterior crural, 529
 femoral, 526
 procerus, 430
 pronator quadratus, 495
 teres, 491
 psoas major, 513
 minor, 514
 pterygoideus externus, 434
 internus, 434
 puboanalis, 471*
 pubococcygeus, 470
 puborectalis, 471
 pubovesicales, 1157, 1159
 pyramidalis abdominis, 464
 nasi, 420
 quadratus femoris, 525
 labii superioris, 430
 inferioris, 430
 lumborum, 467
 plantae, 539
 quadricaps femoris, 518
 recti of eyeball, 970
 rectococcygeal, 1122
 rectovesicales, 1157
 rectus abdominis, 463
 capitis anterior, 443
 anticus major, 442
 minor, 443
 lateralis, 443
 posterior major, 449
 minor, 449

Muscle or muscles (cont.)
 rectus femoris, 518
 rhomboides major, 480
 minor, 480
 of Riolan, 428
 risorius, 432
 rotatores, 448
 sacrospinalis, 445
 salpingopharyngeus, 1079
 sarcolemma, 30
 sarcomere, 31
 sarcoplasm, 31
 sarcostyles, 31
 sarcois element of, 32
 sartorius, 517
 scalenus anterior, 444
 medius, 444
 posterior, 444
 of scalp, 426
 semimembranosus, 527
 semispinalis capitis, 448
 cervicis, 447
 dorsi, 447
 semitendinosus, 527
 serratus anterior, 484
 magnus, 484
 posterior inferior, 451
 superior, 451
 of shoulder, 485
 soleus, 530
 sphincter ani externus, 472
 internus, 473
 pupillae, 959
 recti, 471
 urethrae membranacea, 476, 477
 vaginae, 476, 1190
 vesicae, 1159
 spinalis capitis, 448
 cervicis, 447
 dorsi, 447
 splenius capitis, 445
 cervicis, 445
 stapedius, 991
 sternocleidomastoideus, 438
 sternohyoideus, 441
 sternothyroideus, 441
 striped, 30
 structure of, 30
 vessels and nerves of, 32
 styloglossus, 1068
 stylohyoideus, 440
 stylopharyngeus, 1079
 subanconeus, 490
 subclavius, 483
 subcostales, 451
 subcrureus or articularis
 genus, 519
 suboccipital, 449
 subcapularis, 486
 superficial and lateral cervical, 437
 supinator, 498
 brevis, 498
 longus, 496
 supra- and infrahyoid, 439
 suprasspinatus, 487
 suspensory, of duodenum, 1106
 synergio, 424
 temporalis, 433
 tendons of, 425
 tensor fasciae latae, 517
 tarsi, 428
 tympani, 990
 veli palatini (tensor palati), 1074
 teres major, 485

Muscle or muscles (cont.)
 teres minor, 487
 of thigh, 515
 of thorax, 450
 thyrocartenoides, 1028
 thyroepiglotticus, 1026
 thyrochyoideus, 442
 tibialis anterior, 528
 posterior, 533
 of tongue, 1067
 trachealis, 1030
 trachelomastoideus, 447
 • trapezius, 981
 transversalis cervicis, 447
 transversus abdominis, 462
 auriculæ, 981
 linguæ, 1069
 menti, 431
 nuchæ, 427
 pedis, 540
 perinæi profundus, 476, 477
 superficialis, 473, 476
 thoracis, 451
 trapezius, 478
 triangularis, 430
 sterni, 451
 triceps brachii, 490
 surae, 531
 of trunk, 444
 of tympanic cavity, 900
 of upper extremity, 478
 of ureters, 1159
 unstriped, 32
 structure of, 33
 of urogenital region (female), 476
 (male), 473
 of uvula, 1075
 vastus intermedius, 519
 lateralis, 518
 medialis, 518
 ventricularis, 1026
 vertebral, anterior, 442
 lateral, 444
 verticalis linguæ, 1069
 vocalis, 1026
 volar antibrachial, 491
 voluntary, 30
Muscular fibres of heart, 563
 process of arytenoid cartilage, 1018
 tissue, 30
 cardiac, 33
 striped or voluntary, 30
 unstriped, plain or involuntary, 32
 triangle of neck, 592
Muscularis mucosæ, 1110
Musculi papillares of left ventricle, 504
 of right ventricle, 559
 pectinati of left auricula, 560
 of right auricula, 555
Musculocutaneous nerve of arm, 899
 of leg, 925
Musculophrenic artery, 609
Musculospiral groove, 276
 nerve, 884
 applied anatomy of, 907
Musculus acromioclavicularis, 447
 ocularis, 478
 incisivus labii inferioris, 432
 superioris, 432
 nasolabialis, 432
 suspensorius duodeni, 1108
 uvulae, 1075

Myelencephalon, 91, 761
Myelitis, spinal, 769
Myelocytes, 28
Myeloplaxes, 28
Myenteric plexus, 1114
Mylohyoid artery, 589
 groove, or sulcus, 236
 line, 235
 nerve, 862
Mylohyoides muscle, 441
Myocardium, 562
Myocel, 55, 69
Myology, 423
Nail-fields, primary, 85
Nail matrix, 1011
Nails, 1011
 development of, 85
Nares, 944
Nasal aperture, anterior, 258
 apertures, posterior, 258
 artery, dorsal, 598
 lateral, 584
 bones, 221
 ossification of, 222
 capsule, development of, 76
 cartilages, 943, 944
 cavities, 256, 944
 applied anatomy of, 950
 arteries of, 948
 lymphatic vessels of, 717
 mucous membrane of, 947
 nerves of, 948
 veins of, 948
 vestibule of, 945
 concha, inferior, 220
 ossification of, 220
 middle, 219
 superior, 219
 crest, 229
 duct, 978
 index, 261
 laminae, 80
 mucous membrane, 947
 nerves from anterior ethmoidal, 855
 external from maxillary, 858
 posterior inferior from anterior palatine, 859
 from sphenopalatine ganglion, 859
 notch of frontal bone, 214
 of maxilla, 224
 part of frontal bone, 214
 of pharynx, 1076
 process of frontal bone, 214
 processes of foetus, 79
 septum, 256, 946
 spine, anterior, 224, 229
 posterior, 230, 243
 surface of maxilla, 225
Nasalis muscle, 429
Nasion, 260
Nasmyth's membrane, 1062
Nasociliary nerve, 855
Nasofrontal vein, 686
Nasolabialis muscle, 432
Nasolacrimal duct, 978
Naso-optic furrow, 80, 106
Nasopalatine nerve, 859
 groove, 222
 recess, 946
Nasopharynx, 1076
Navicular bone of carpus, 200
 ossification of, 297
 of tarsus, 332
 ossification of, 338
 foam, 1192

Neck, lymph-glands of, 714
 lymphatic vessels of, 718
 muscles of, 436
 surface anatomy of, 1223
 triangles of, 691
 veins of, 676
Neck of rib, ligament of, 360
Necrosis, acute infective, of bone, 25
Nélaton's line, 1260
Neopallium, 97
Nephrectomy, 1151
Nephrogenic cord, 52
Nephrolithotomy, 1151
Nephropexy, 1151
Nephrotomy, 1151
Nerve-cells, 35
 axon or axis-cylinder process of, 35
 bipolar, 35
 of cerebellar cortex, 781
 of cerebral cortex, 829
 dendrons or protoplasmic processes of, 36
 of medulla spinalis, 751
 multipolar, 35
 unipolar, 35
Nerve-deafness, 874, 1005
Nerve-endings, free, 1005
Nerve fasciculi of medulla spinalis, 754
Nerve-fibres, 37
 of cerebral cortex, 829
 grey or gelatinous 40
 medullated, 37
 non-medullated, 40
 of Remak, 40
 preganglionic, 740
 postganglionic, 740
 white, 37
Nerve-roots, anterior, 758, 885
 posterior, 758, 885
Nerve or nerves—
 abducent, 865
 accessory, 881
 cerebral part, 881
 spinal part, 882
 acoustic, 872, 1004
 development of, 109
 afferent or centripetal, 742
 alveolar, anterior superior, 858
 middle, 858
 posterior, 857
 inferior, 862
 anococcygeal, 927
 anterior crural, 916
 interosseous, 901
 superior alveolar, 858
 thoracic, 897
 tibial, 925
 antibrachial cutaneous, dorsal, 905
 lateral, 899
 medial, 900
 Arnold's, 879
 auricular anterior, of auriculotemporal, 861
 great, 892
 posterior, 870
 of vagus, 879
 auriculotemporal, 861
 autonomic, 741
 axillary, 899
 of Bell, 897
 brachial cutaneous, lateral, 899
 medial, 901
 posterior, 905

Nerve or nerves (cont.)

bronchial, anterior, 880
 posterior, 880
 buccal, of facial, 870
 long, 860
 buccinator, 860
 calcaneal, medial, 923
 cardiac, of sympathetic, 932, 933
 of vagus, 886
 carotico tympanic, 931, 991
 carotid, of glossopharyngeal, 876
 internal, 931
 cavernous, of penis, 940
 centrifugal or efferent, 742
 centripetal or afferent, 742
 cerebral, 846
 abducent, 865
 accessory, 881
 acoustic, 872
 development of, 100
 facial, 867
 glossopharyngeal, 875
 hypoglossal, 883
 oculomotor, 851
 olfactory, 847
 development of, 100
 optic, 848
 trigeminal, 853
 trochlear, 852
 vagus, 877
 cerebrospinal, structure of, 741
 cervical, anterior divisions of, 891
 posterior divisions of, 887
 cutaneous or transverse, 893
 of facial, 871
 chorda tympani, 870, 992
 ciliary, long, 855
 short, 856
 circumflex, 899
 clunium inferiores, 920
 medii, 890
 coccygeal, anterior division of, 917
 posterior division of, 890
 cochlear, 873, 1004
 coliac, of vagus, 881
 common peroneal, 924
 communicans fibularis, 924
 tibialis, 923
 communicantes cervicales, 894
 crural, anterior, 916
 cutaneous cervical, 893
 internal, 900
 lesser internal, 901
 deep branch of radial, 906
 of ulnar, 904
 peroneal, 925
 petrosal, 858
 temporal, 860
 dental, inferior, 862
 descendens cervicalis, 894
 descending ramus of hypoglossal, 884
 development of, 88, 100
 digastric, from facial, 870
 digital, of lateral plantar, 924
 of medial plantar, 923
 of median, 903
 of radial, 905
 of superficial peroneal, 925
 of ulnar, 904

Nerve or nerves (cont.)

dorsal antibrachial cutaneous, 905
 branch of ulnar, 903
 of clitoris, 926
 cutaneous, intermediate, 925
 lateral, 923
 medial, 925
 of penis, 926
 scapular, 896
 of dura mater, 841
 efferent or centrifugal, 742
 endings, free, 1005
 end-organs, special, 1005
 endoneurium of, 741
 epineurium of, 741
 ethmoidal, anterior, 855
 posterior, 856
 external cutaneous, of musculospiral, 905
 of thigh, 913
 external nasal, 855, 858
 petrosal, 932
 popliteal, 924
 saphenous, 923
 spermatic, 913
 facial, 867
 motor fibres, 867
 sensory fibres, 868
 femoral, 916
 cutaneous, anterior, 916
 lateral, 913
 posterior, 920
 frontal, 855
 funiculi of, 741
 furcal, 911
 ganglia of, 743
 gastric branches of vagus, 881
 genitofemoral or genitocrural, 913
 glossopharyngeal, 875
 motor fibres, 875
 sensory fibres, 875
 gluteal, inferior, 920
 superior, 920
 great auricular, 892
 greater occipital, 888
 splanchnic, 934
 superficial petrosal, 858, 869
 hæmorrhoidal, inferior, 926
 hepatic branches of vagus, 881
 hypoglossal, 882
 iliohypogastric, 912
 ilioinguinal, 913
 incisive, 862
 inferior dental, 862
 maxillary, 860
 infraorbital, 856*
 infrapatellar, 917
 infratrochlear, 856
 intercostal, 908
 thoracic, 909
 thoraco-abdominal, 910
 intercostobrachial, 910
 intermedius of Wrisberg, 867
 internal carotid, 931
 cutaneous, of arm, 900
 lesser, 901
 of musculospiral, 905
 popliteal, 923
 saphenous, 916
 interosseous, dorsal, 906
 posterior, 906
 volar or anterior, 901

Nerve or nerves (cont.)

Jacobson's, 876, 991
 jugular, 932
 labial, posterior, 926
 superior, 858
 lacrimal, 855
 laryngeal, recurrent, 880
 superior, 879
 laryngopharyngeal, of sympathetic, 932
 lateral antibrachial cutaneous, 899
 brachial cutaneous, 899
 dorsal cutaneous, 923
 femoral cutaneous, 913
 plantar, 923
 lesser splanchnic, 934
 lingual, 862
 of glossopharyngeal, 876
 long ciliary, 855
 saphenous, 916
 subscapular, 899
 thoracic, 897
 lowest splanchnic, 934
 lumbar, anterior divisions of, 911
 posterior divisions of, 890
 lumbo-inguinal, 913
 lumbosacral trunk, 911
 mandibular, 859
 of facial, 871
 masseteric, 860
 masticatorius, 860
 maxillary, 856
 inferior, 859
 medial antibrachial cutaneous, 900
 brachial cutaneous, 901
 plantar, 923
 sural cutaneous, 923
 median, 901
 meningeal, of hypoglossal, 884
 of maxillary, 857
 middle, 857
 of spinal nerves, 887
 of vagus, 879
 mental, 862
 motor, 743
 ending in involuntary or unstriped muscles, 743
 in voluntary or striped muscles, 743
 musculocutaneous of arm, 899
 of leg, 925
 musculospiral, 904
 mylohyoid, 862
 nasal, external, 855, 858
 internal, 855
 posterior, inferior, 859
 superior, 859
 from sphenopalatine ganglion, 859
 nasociliary, 855
 nasopalatine, 859
 nervi nervorum, 742
 obturator, 913
 accessory, 916
 of obturator internus and gemellus inferior, 920
 occipital, greater, 858
 smaller, 891
 third, 888
 oculomotor, 851
 oesophageal, 880
 olfactory, 847, 948
 development of, 102

Nerve or nerves (cont.)

ophthalmic, 854
 optic, 848
 orbital, their relation, in
 cavernous sinus, 866
 in orbit, 866
 in superior orbital fissure, 866
 branches of sphenopalatine ganglion, 858
 origins of, 742
 palatine, anterior, 859
 middle, 859
 posterior, 859
 palmar cutaneous, of median, 903
 of ulnar, 903
 palpebral, inferior, 858
 perforating cutaneous, 926
 perineal, 926
 superficial, 926
 perineurium of, 741
 peripheral terminations of, 742
 peroneal anastomotic, 924
 peroneal, common, 924
 deep, 925
 superficial, 925
 petrosal, deep, 858, 931
 external, 932
 greater superficial, 858, 869
 smaller superficial, 886, 991
 pharyngeal, of glossopharyngeal, 876
 of sphenopalatine ganglion, 859
 of vagus, 879
 phrenic, 894
 to piriformis, 920
 plantar, lateral or external, 923
 medial or internal, 923
 plexus, 742
 popliteal, external, 924
 internal, 922
 of pterygoid canal, 858
 to pterygoideus externus, 860
 internus, 860
 pudendal, 926
 inferior, 920
 pudic, 926
 to quadratus femoris and gemellus inferior, 919
 radial, 904
 deep branch, 906
 superficial branch, 905
 rami communicantes, grey and white, 887, 928, 930
 ramus colli, 871
 marginalis mandibulae, 871
 recurrent, 880
 roots, 758, 885
 sacral, anterior divisions of, 917
 posterior divisions of, 890
 saphenous, 916
 external, 923
 scapular, dorsal, 896
 sciatic, 920
 small, 920
 scrotal, posterior, 926
 short ciliary, 856
 smaller occipital, 891
 special end-organs of, 1005
 spermatic, external, 913
 sphenoidal, of otic ganglion, 863

Nerve or nerves (cont.)

sphenopalatine branches of
 maxillary, 857
 spinal, 885
 anterior divisions of, 891
 posterior divisions of, 887
 connexions with sympathetic trunks, 887
 development of, 88
 ganglia of, 885
 roots of, 758, 885
 size and direction, 885
 somatic fibres of, 887
 sympathetic fibres of, 887
 spinal accessory, 881
 spinosus, 860
 splanchnic, greater, 934
 lesser, 934
 lowest, 934
 to stapedius, 870
 to stylohyoid, 870
 to stylopharyngeus, 876
 to subclavius, 897
 suboccipital, 885, 887
 subscapular, 898
 long, 899
 substance, grey, 34
 white, 34
 superficial branch of radial, 905
 of ulnar, 904
 peroneal, 925
 petrosal, greater, 858
 superior labial, 858
 supraclavicular, 893
 supraorbital, 865
 suprascapular, 897
 supratrochlear, 855
 sural, 923
 cutaneous lateral, 924
 medial, 923
 sympathetic, 928
 structure of, 742
 of taste, 943
 temporal, deep, 860
 superficial, 862
 of facial, 870
 temporomalar, 857
 terminations of, 742
 thoracic, anterior divisions
 of, 908
 first, 908
 lateral anterior, 897
 long, 897
 medial anterior, 897
 posterior divisions of, 889
 twelfth, 910
 thoracodorsal, 899
 thyrohyoid, 884
 tibial, 922
 anterior, 925
 of tongue, 1071
 tonsillar, 876
 transverse cervical, 893
 trigeminal, 853
 trochlear, 852
 tympanic, of glossopharyngeal, 876, 991
 ulnar, 903
 collateral, 904
 of urethral bulb, 926
 vagus, 876
 motor fibres, 877
 sensory fibres, 877
 vasomotor fibres, 742
 vestibular, 872, 1004
 Vidian, 858

Nerve or nerves (cont.)

volar digital, 903, 904, 905
 interosseous, 901
 of Wrisberg, 901
 zygomatic, 857
 of facial, 870
 zygomaticofacial, 857
 zygomaticotemporal, 857
 Nervi erigentes, 935
 nervorum, 742
 Nervous system, development
 of, 85
 cerebrospinal, central part,
 740
 peripheral, part 740
 sympathetic, 740, 928
 tissue, 34
 Nervus communicans fibularis,
 924
 tibialis, 923
 furcalis, 911
 intermedius, of. Wrisberg,
 867
 masticatorius, 860
 spinosus, 860
 Network, dorsal carpal, 622
 lateral malleolar, 665
 medial malleolar, 665
 volar carpal, 622, 625
 Neumann, dentinal sheath of,
 1058
 Neural canal, 53
 crest, 53, 88
 folds, 53
 groove, 53
 tube, 53
 Neurenteric canal, 53
 Neuroblasts, 86
 Neurocentral synchondroses,
 176
 Neuroglia, 35
 Neurokeratin, 38
 Neurolemma, 38, 39
 Neurology, 740
 Neuromeres, 746
 Neuromuscular spindles, 1007
 Neuron theory, 744
 Neurons, association or inter-
 segmental, 751
 highest sensory, 837
 intermediate sensory, 837
 lower motor, 836
 lowest sensory, 837
 upper motor, 836
 Neuropore, anterior, 53
 posterior, 53
 Neurotendinous spindles, 1007
 Neutrophil colourless cor-
 puscles, 28
 Nidus avis of cerebellum, 778
 Ninth thoracic vertebra, 169
 Nipple or mammary papilla,
 1102
 Nissl's granules, 36
 Node, atrioventricular, 564
 sino-atrial, 564
 Nodes of Parrot, 264
 of Ranvier, 39
 Nodule of cerebellum, 777
 Nodules, aggregated lymphatic,
 1113
 solitary lymphatic, 1112,
 1123
 Non-medullated nerve-fibres,
 40
 Norma basalis, 241
 frontalis, 248
 lateralis, 244

Norma occipitalis, 247
verticalis, 241
Normoblasts, 28
Noose, 943
 accessory sinuses of, 949
 ala nasi, 943
 alar cartilages of, 944
 apex of, 943
 applied anatomy of, 950
 arteries of, 948
 base of, 943
 bridge of, 943
 cartilage of septum of, 943
 cartilaginous framework of, 943
 cavities of, 944
 choanae, 945
 columnae of, 943
 development of, 79
 dorsum, 943
 external, 943
 lateral cartilage of, 944
 lymphatics of, 717
 meatuses of, 945, 946
 mucous membrane of, 947
 muscles of, 429
 nares, 943, 944
 nerves of, 948
 septum mobile nasi, 944
 veins of, 948
Notch, acetabular, 303
 anterior cerebellar, 775
 cardiac, 1040
 ethmoidal, 216
 fibular, 320, 321
 frontal, 214
 great scapular, 268
 intertragic, 980
 jugular, 182, 196
 lacrimal, 225
 mandibular, 237
 mastoid, 205
 nasal, of frontal bone, 214
 of maxilla, 224
 parietal, 204
 posterior cerebellar, 775
 pre-occipital, 805
 radial, 285
 of Rivinus, 985
 scapular, 268
 sciatic, greater, 301
 lesser, 301
 semilunar, 284
 sphenopalatine, 232, 233
 superior thyroid, 1017
 supraorbital, 214, 248, 249
 ulnar, of radius, 282
Notches, cerebellar, 775
 vertebral, 162
Notochord, 54
Nuchal line, highest, 193
 inferior, 193, 244
 median, 193, 248
 superior, 193, 244
 fascia, 444
Nuck, canal of, 152, 1187
Nuclear layer of cerebellar cortex, 781
 layers of retina, 962, 963
 membrane, 2
Nucleated sheath of Schwann, 38, 39
Nuclei of acoustic nerve, 775
 873
 of cochlear nerve, 775, 873
 of glossopharyngeal nerve, 768, 875
 of oculomotor nerve, 851

Nuclei, olivary, 768
 of origin of cerebral nerves, 846
 pontis, 773
 of termination of cerebral nerves, 846
 of trigeminal nerve, 774, 854
 of vestibular nerve, 775, 873
Nucleolus, 2
Nucleus of abducent nerve, 774
 of accessory nerve, 768, 881
 ambiguus, 766, 768, 875, 881
 amygdala, 821
 arcuatus, 771
 of Bechterew, 775, 873
 caudate, 819
 of a cell, 2
 cervical, 752
 cuneatus, 764
 of Deiters, 775, 873
 dentatus of cerebellum, 782
 dorsal, of medulla spinalis, 751
 emboliformis, 782
 of facial nerve, 775, 867
 fastigii, 782
 globosus, 782
 gracilis, 764
 of hypoglossal nerve, 768, 882
 intercalatus, 786
 of lateral lemniscus, 873
 lateralis, 771
 lentiform (or lenticular), 819
 of Luys, 799
 of medial longitudinal fasciculus, 790
 of oculomotor nerve, 851
 olivary, 768
 of posterior commissure, 798
 purposus, 71, 350
 red, 789
 of Roller, 771
 sacral, 752
 segmentation, 48
 superior olivary, 774
 tractus solitarius, 808, 875
 trapezoid, 773
 of trochlear nerve, 793, 852
 of vagus, 768, 877
Nuel, space of, 1003
Nuhn, glands of, 1070
Nutrient artery of bone, 19
Nutritive yolk, 41
Obelion, 261
Obex, 785
Oblique cord, 377
 diameter of pelvis, 305
 inguinal hernia, 1125
 line of the fibula, 323
 of mandible, 235
 of radius, 282
 of thyroid cartilage, 1017
 popliteal ligament, 403
 ridge of clavicle, 271
 sinus of pericardium, 552
 vein of left atrium, 126, 552, 672
 vein of Marshall, 126, 552, 672
Obliquus auriculae, 981
 capitis inferior, 449
 superior, 449
 externus abdominis, 458
 internus abdominis, 460
 oculi inferior, 970
 superior, 970

Obliterated umbilical vein, 1086
Obturator artery, 645
 peculiarities of, 646
 relation of, to femoral ring, 646
 crest, 303
 externus muscle, 525
 foramen, 303
 groove, 303
 internus muscle, 524
 fascia, of 467
 lymph-glands, 725
 membrane, 524
 nerve, 913
 applied anatomy of, 927
 accessory, 916
 tubercle, anterior, 303
 posterior, 301, 303
 vein, 700
Obtuse margin of heart, 555
Occipital artery, 585
 bone, 193
 basilar part of, 196
 lateral parts of, 195
 ossification of, 196
 squama of, 193
 structure of, 196
 condyles, 195
 crest, internal, 194, 255
 fonticulus, 195
 fossae, 194
 groove, 205
 lobe, 809
 lymph-glands, 713
 nerve, greater, 888
 smaller, 891
 third, 888
 plate, 73
 point, 261
 protuberance, external, 193, 248
 internal, 194
 sinus, 682
 sulcus, lateral, 809
 transverse, 809
 triangle, 593
 vein, 674
Occipitalis, 427
Occipito-axial ligament, 358
Occipitofrontal or longitudinal arc of skull, 261
Occipitofrontal fasciculus, 829
Occipitofrontalis muscle, 426
Occipitomastoid suture, 245
Ocular muscles, 968
 applied anatomy of, 973
Oculomotor sulcus, 787
 nerve, 851
 applied anatomy of, 852
Odontoblasts, 1058, 1062
Odontoid process of epistropheus or axis, 165
Odontoma, 1064
Oedema of the glottis, 1030
Oesophageal arteries, 610, 629
 glands, 1082
 hiatus in diaphragm, 463
 impression on liver, 1136
 nerves, 878
 plexus, 878, 880
Oesophagus, 1080
 abdominal portion of, 1081
 applied anatomy of, 1082
 cervical portion of, 1080
 lymphatic vessels of, 739
 structure of, 1081
 thoracic portion of, 1081
 vessels and nerves of, 1083

- Clecranon**, 284
fossa, 277
Clacfactory areas, 79
 bulb, 812, 833
 structure of, 833
 cells, 948
 fasciculus, 825
 hair, 948
 lobe, 812
 nerves, 847, 948
 applied anatomy of, 848
 development of, 102
 • **pits**, 79
 region of nasal cavities, 945, 947
 sulcus of frontal lobe, 808
 of nasal cavity, 946
 • **tract**, 812
 trigone, 813
Olive, 763
 peduncle of, 769
Olivary nucleus, dorsal ac-
 cessory, 769
 inferior, 768
 medial accessory, 769
 superior, 774
Olivospinal fasciculus (Hel-
weg), 756
Omental bursa, 1088, 1091
 boundaries of, 1092
 recess, inferior, 1092
 linal, 1092
 middle, 1092
 superior, 1092
 vestibule of, 1092
Omentum, gastrosplenis, 1091
 greater, 1094
 lesser, 1094
Omohyoidens muscle, 442
Oöcytes, primary, 41
 secondary, 44
Oögonia, 41
Oöplasm, 41
Open part of medulla oblon-
gata, 761
Opening of aorta in left ven-
tricle, 561
 aortic, in diaphragm, 453
 atrioventricular, left, 561
 right, 558
 of coronary sinus, 556
 of inferior vena cava, 556
 oesophageal, in diaphragm,
 453
 of pulmonary artery, 558
 veins, 560
 saphenous, 516
 of superior vena cava, 556
 of thorax, lower, 550
 upper, 550
 vena-caval, in diaphragm,
 453
Openings in diaphragm, 453
 in roof of fourth ventricle, 785
Opercula of insula, 811
Ophryon, 261
Ophthalmic artery, 596
 nerve, 854
 veins, 685
Optation, 261
Optic centre of temporal
bone, 216
Opponens digiti quinti, of hand,
 566, **of foot**, 540
 pollicis, 506
Optic axis, 861
 oblique of commissure, 862,
 863
Optic bulb, 102
 cup, 102
 disc, 961
 foramen, 197, 201, 252
 groove, 197
 nerve, 848
 applied anatomy of, 850
 radiations, 796, 802
 recess, 803
 stalks, 94, 102
 tracts, 802
 vesicles, 94, 102
Ora serrata, 960, 964
Oral part of pharynx, 1077
Orbicular ligament, 376
Orbicularis oculi, 428
 ciliary bundle of, 428
 lacrimal part of, 428
 orbital part of, 428
 palpebral part of, 428
 oris, 431
Orbiculus ciliaris, 957
Orbital fascia, 972
 fissure, inferior, 246
 superior, 200, 251, 253
 gyri, 808
 index, 261
 nerves, from sphenopalatine
 ganglion, 859
 operculum, 811
 plates of frontal bone, 215
 process of palatine bone, 232
 of zygomatic bone, 234
 septum, 975
 sulcus, 808
 surface of maxilla, 225
 vein, 674
Orbitalis muscle of Müller, 971
Orbits, 249
 relation of nerves in, 866
Orchitis, 1168
Organ, enamel, 1061
 of Giralde's, 1169
 of hearing, 979
 of Rosenmüller, 147, 1181
 of sight, 951
 of smell, 943
 spiral, of Corti, 1001
 of taste, 942
Organic reflexes, 838
Organs, accessory, of the diges-
tive tubo, 1046
 of the eye, 968
 chromaffin, 101
 genital, of female, 1178
 external, 1191
 of male, 1164
 development of, 145
 of Golgi, 1007
 of the senses, 942
 peripheral, of the special
 senses, 942
 urinary, 1143
 vomeranasal, of Jacobson,
 82, 947
Orifice, aortic, 561
 atrioventricular, left, 561
 right, 558
 cardiac, of stomach, 1098
 of mouth, 1046
 of pulmonary artery, 558
 pyloric, of stomach, 1098
 urethral, external, in female,
 1192
 in male, 1162
 internal, 1158
 of uterus, external, 1185
 internal, 1184
Orifice, vaginal, 1192
Orifices of ureters, 1158
Origin of muscles, 424
Origins of nerves, 742
Os acetabuli, 304
 calcis, 331
 capitatum, 293
 centrale, 297
 coceygis, 176
 cordis, 562
 coxae, 295
 ossification of, 304
 structure of, 304
 cuboldeum, 335
 cuneiforme primum, 333
 secundum, 333
 tertium, 334
 ethmoidale, 217
 frontale, 213
 hamatum, 293
 hypoideum, 240
 illi, 298
 incisivum, 229
 innominatum, 298
 ischii, 301
 lunatum, 291
 magnum, 293
 multangulum majus, 292
 minus, 292
 naviculare manus, 290
 pedis, 332
 occipitale, 193
 pisiforme, 291
 planum of ethmoidal bone,
 218
 pubis, 302,
 angle, 302
 body, 302
 crest, 302
 iliopectineal eminence, 303
 obturator crest, 303
 pecten, 302
 ramus, inferior, 302
 superior, 302
 spine, 302
 tubercle, 302
 sacrum, 171
 sphenoidale, 197
 trigonum, 330, 338
 triquetrum, 291
Ossa carpi, 290
 cranii, 193
 faciei, 224
 lacrimalia, 220
 metacarpalia, 294
 metatarsalia, 335
 nasalia, 221
 palatina, 230
 parietalia, 211
 suturarum, 224
 tarsi, 325
 temporalia, 203
Ossein, 21
Osseous spiral lamina, 996
labyrinth, 993
Ossicle, pterion, 224
Ossicles, auditory, 988
 incus, 989
 malleus, 989
 stapes, 990
 development of, 106
 ligaments of, 990
Ossification, centre of, 22
 intracartilaginous, 22
 intramembranous, 21
Ossification of—
 atlas, 177
 axis, 177

Ossification of (cont.)

- carpals, 296
 - clavicle, 273
 - coccyx, 179
 - epistropheus, 177
 - ethmoidal, 220
 - femur, 316
 - fibula, 324
 - foot, 338
 - frontal, 216.
 - hand, 296
 - hip-bone, 304
 - humerus, 278
 - hyoid, 241
 - inferior nasal concha, 220
 - lacrimal, 221
 - lumbar vertebrae, 178
 - mandible, 237
 - maxilla, 229
 - metacarpals, 297
 - metatarsals, 338
 - nasal, 222
 - occipital, 196
 - os coxae or innominatum, 304
 - palatine, 233
 - parietal, 213
 - patella, 325
 - phalanges of fingers, 297
 - of toes, 330
 - radius, 283
 - ribs, 189
 - sacrum, 178
 - scapula, 270
 - seventh cervical vertebra, 178
 - sphenoidal, 202
 - sternum, 184
 - tarsals, 338
 - temporal, 210
 - titia, 321
 - ulna, 286
 - vertebral column, 176
 - vomer, 222
 - zygomatic, 234
- Osteo-arthritis**, of hip, 390
- Osteoblasts**, 18, 21, 22
- Osteoclasts**, 23, 1063
- Osteogenetic fibres**, 22
- Osteology**, 160
- Osteomalacia**, 309
- Osteomyelitis**, 25
- Ostium**, abdominal, of uterine tube, 1182
- maxillare, 946
- pharyngeal, of auditory tube, 1076
- primitive urogenital, 155
- primum, of heart, 115
- secundum, of heart, 115
- Otic ganglion**, 862
- Otoconia**, 998
- Otocyst**, 106
- Outlet of pelvis**, 306
- Ova**, holoblastic, 48
- human, 41
- meroblastic, 48
- primitive, 150
- Oval area of Flechsig**, 758
- bundle, 88, 92
- Ovarian arteries**, 641
- cysts, 1181
- fimbria, 1182
- fossa, 1090, 1178
- plexus of nerves, 939
- pregnancy, 47
- veins, 703

Ovaries, 1178

- applied anatomy of, 1181
 - descent of, 152
 - development of, 150
 - ligaments of, 1180
 - lymphatic vessels of, 735
 - structure of, 1180
 - vessels and nerves of, 1181
 - vesicular or Graafian follicles of, 1180
- Ovariectomy**, 1181
- Ovula Nabothi**, 1189
- Ovum**, 41
- corona radiata of, 43
 - coverings of, 42
 - discharge of, 1181
 - fertilisation of, 47
 - germinal spot of, 41
 - vesicle of, 42
 - implantation or imbedding of, 63
 - maturation of, 43
 - mature, 43
 - segmentation of, 48
 - structure of, 41
 - yolk of, 41
 - zona pellucida or zona striata of, 42
- Owen**, contour lines of, 1059
- Oxyntic cells**, 1104
- glands, 1104
- Oxyphil colourless corpuscles**, 28
- Pacchionian glands**, 844
- Pacinian corpuscles**, 1006
- Pachydermia lymphangiectatica**, 710
- Pad**, infrapatellar, 401
- retropubic, 1155
- strotorial, 431
- Palate**, 1048
- aponeurosis of, 1073
 - applied anatomy of, 1048
 - arches of, 1072
 - cleft, 264
 - development of, 80
 - hard, 1048
 - primitive, 80
 - soft, 1048
 - muscles of, 1074
 - mucous membrane of, 1048
 - paralysis of, 1048
 - vessels and nerves of, 1048
- Palatine aponeurosis**, 1073
- artery, ascending, 583
- descending, 590
- applied anatomy of, 590
- greater, 500
- bone, 230
- horizontal part of, 230
 - maxillary process of, 232
 - orbital process of, 232
 - ossification of, 233
 - pyramidal process of, 232
 - tuberosity of, 232
 - sphenoidal process of, 232
 - vertical part of, 231
- foramen, greater, 243
- foramina, lesser, 243
- nerves, 589
- process of maxilla, 228
- processes of fetus, 80
- tonsils, 1072
- development of, 131
- lymphatic vessels of, 717
- uvula, 1048
- velum, 1048

Palatoglossus, 1075

- Palatopharyngeus**, 1075
- Palmar aponeurosis**, 504
- applied anatomy of, 505
 - arch, deep, 623
 - superficial, 627
 - cutaneous branch of median nerve, 903
 - of ulnar nerve, 903
 - ganglion, compound, 506
- Palmaris brevis**, 508
- longus, 492
- Palmate folds of cervix uteri**, 1185
- Palpebrae**, 973
- Palpebral arteries**, lateral, 597
- medial, 598
- commissures or canthi, 974
 - fiassure, 973
 - ligament, medial, 429
 - nerves from maxillary, 858
 - raphe, lateral, 429
- Pampiniform plexus**, 702
- Pancreas**, 1128
- accessory duct of, 141, 1132
 - applied anatomy of, 1132
 - body of, 1130
 - development of, 141
 - duct of, 141, 1131
 - head of, 1128
 - lymphatic vessels of, 732
 - neck of, 1130
 - relations of, 1128
 - structure of, 1132
 - surface marking of, 1239
 - tail of, 1131
 - uncinate process of, 1128
 - vessels and nerves of, 1132
- Pancreatic branches of splenic (lienal) artery**, 635
- duct, 141, 1131
- accessory, 141, 1132
- veins, 705
- Pancreatica magna artery**, 635
- Pancreaticoduodenal artery**, inferior 636
- superior, 635
- veins, 706
- Pancreaticolymph-glands**, 727, 731
- Pannus**, 966
- Papilla**, lacrimal, 974
- foliata, 1071
- mammary, 1192
- of optic nerve, 961
- Papillae lacrimales**, 977
- of skin, 1011
- of tongue, 1065, 1066
- structure of, 1070
- Papillary layer of skin**, 1010
- process, 1136
- Paracardial lymph-glands**, 727
- Paracentesis of pericardium**, 553
- Paracentral lobule**, 808
- Parachordal cartilages**, 74
- Paradidymis**, 147, 1169
- Parallel sulcus**, 810
- Paralyses**, alternate, 775
- conjugate, 775
- lower segment, 775
- Paralysis**, infantile, 25, 760
- motor, 838
- sensory, 838
- of cervical sympathetic, 940
- Paramastoid process**, 196
- Paramedial sulcus**, 808
- Parametritis or pelvic cellulitis**, 1190

- Parametrium, 1185
 Paraneuphric body, 1147
 Paraneucleus, 1132
 Paraplast, 2
 Pararectal fossa, 1089
 lymph-glands, 729
 Paraseptal cartilage, anterior,
 77
 common, 76
 posterior, 77
 Parathyroid glands, 1198
 applied anatomy of, 1198
 development of, 131
 structure of, 1198
 Paratracheal lymph-glands, 715
 Paravesical fossa, 1089, 1154
 Paraxial mesoderm, 52
 Parenchyma of lung, 1042
 Parietal bone, 211
 ossification of, 213
 cells of fundus glands, 1104
 eminence, 211, 241, 245
 foramen, 211
 lobe, 808
 gyr of, 809
 sulci of, 809
 lymph-glands of abdomen
 and pelvis, 724
 of thorax, 735
 notch, 204
 operculum, 811
 pleura, 1031
 tuberosity, 211, 241, 245
 veins of embryo, 123
 emissary, 686
 Parietes, development of, 69
 Parietomastoid suture, 245
 Parieto-occipital fissure, 807
 Parietotemporal artery, 600
 Parolfactory area of Broca,
 813
 Paronychia, 505
 Paroöphoron, 147, 1181
 Parosmia, 848
 Parotid duct, 1050
 surface marking of, 1217
 gland, 1049
 accessory part of, 1049
 applied anatomy of, 1054
 surface marking of, 1217
 vessels and nerves of, 1051
 lymph-glands, 714
 plexus, 869
 Parotideomasseteric fascia, 435
 Parrot's nodes, 264
 Pars analis recti, 1121
 ciliaris retinae, 103, 958,
 960, 964
 endopelvina fasciæ pelvis,
 469
 flaccida of tympanic mem-
 brane, 986
 intermedia of vestibular
 bulb, 1192
 iridica retinae, 103, 959, 960,
 964
 mamillar hypothalami, 95
 optica hypothalami, 95
 tensa of tympanic membrane,
 986
 uterina tubæ, 1182
 Parumbilical veins, 706
 Patella, 324
 applied anatomy of, 325
 movements of, 407
 ossification of, 325
 structure of, 325
 surface anatomy of, 1254
 Patellar fold, 401
 plexus, 913, 917
 retinacula, 400
 surface of femur, 314, 315
 Pavement epithelium, 4
 Pecten pubis, 302
 Pectinate ligament of iris, 955
 Pectineal line, 312
 Pectineus muscle, 520
 Pectiniform septum, 1173
 Pectoral fascia, 481
 Pectoralis major, 482
 minor, 483
 Peculiarities in vascular system
 of foetus, 566
 Pedicles of a vertebra, 161
 Peduncle of corpus callosum,
 813
 of olive, 769
 Peduncles, cerebellar, 778, 779
 cerebral, 787
 Pedunculated hydatid, 1165
 Pelvic brim, 305
 cellulitis, 1190
 colon, 1118
 curve of vertebral column,
 179
 diaphragm, 467, 1084
 fascia, 467
 diaphragmatic part of, 468
 endopelvic part of, 469
 girdle, 265
 plexuses, 940
 portion of sympathetic sys-
 tem, 935
 splanchnic nerves, 930
 Pelvis, 305, 1084
 applied anatomy of, 308
 axes of, 306
 brim of, 305
 cavity of lesser, 305
 diameters of, 305, 306
 in foetus, 308
 greater or false, 305
 inferior aperture or outlet
 of, 306
 inlet of, 305
 lesser or true, 305
 linea terminalis of, 305
 lymph-glands of, 724
 lymphatic vessels of, 729
 major, 305
 male and female, differences
 between, 307
 mechanism of, 391
 minor, 305
 muscles of, 467
 in osteomalacia, 309
 outlet of, 306
 position of, 306
 renal, 1146
 in rickets, 309
 superior aperture or inlet of,
 305
 surface anatomy of, 1254
 Penis, 1173
 applied anatomy of, 1175
 body of, 1174
 corona glandis, 1174
 corpora cavernosa, 1173
 corpus cavernosum urethrae
 or corpus spongiosum,
 1173
 crura of, 1173
 deep artery of, 647
 dorsal artery of, 647
 nerve of, 926
 veins of, 701
 Penis, extremity of, 1174
 fundiform ligament of, 1174
 glans, 1174
 neck of, 1174
 nerves of, 1175
 prepuce or foreskin of, 1174
 root of, 1174
 septum pectiniforme of, 1173
 structure of, 1175
 suspensory ligament of, 1174
 vessels and nerves of, 1175
 Perforated substance, anterior,
 813
 posterior, 787
 Perforating arteries, of hand,
 623
 from internal mammary,
 609
 from peroneal, 668
 from plantar arch, 669
 from profunda femoris,
 668
 cutaneous nerve, 926
 fibres of bone, 20
 Perforator of spermatozoön, 44
 Pericardiacophrenic artery, 609
 Pericardial area, 51
 arteries, 609, 629
 Pericardiotomy, 553
 Pericardium, 551
 applied anatomy of, 553
 fibrous, 551
 nerves of, 562
 oblique sinus of, 552
 relations of, 551
 serous, 551
 structure of, 551
 transverse sinus of, 552
 vessels of, 552
 vestigial fold of, 552
 Perichondrium, 15, 22
 Perichorioid lymph-space,
 951
 Perilymph, 996
 Perimetritis, 1183
 Perimysium, 30
 Perineal artery, 647
 transverse, 647
 body, 1121
 branch of fourth sacral
 nerve, 927
 ectopia testis, 1167
 flexure of rectum, 1120
 nerve, 926
 nerves, superficial, 926
 Perineum, boundaries of, 471
 central tendinous point of,
 473
 lymphatic vessels of, 730
 muscles of, 471
 Perinephric abscess, 1151
 Perineurium, 741
 Periods of activity and rest of
 cardiac cycle, 565
 Periostrum, 17
 internal, 17
 Periostitis, acute infective, 25
 Peripheral end-organs, 1005
 Peripheral organs of the special
 senses, 942
 terminations of motor nerves,
 743
 of nerves of general sensa-
 tions, 1005
 Periscleral lymph-space, 972
 Peritoneal cavity, 1086
 fossa or recesses, 1097
 applied anatomy of, 1098

- Peritoneum, 1086**
 epiploic foramen of, 1091
 lesser sac or omental bursa of, 1094
 ligaments of, 1094
 main cavity or greater sac of, 1091
 horizontal disposition of, in lower abdomen, 1090
 in upper abdomen, 1090
 in pelvis, 1090
 vertical disposition of, 1086
 mesenteries of, 1095
 omenta of, 1094
 omental bursa of, 1091
 vertical disposition of, 1088
 parietal portion of, 1086
 recesses or fossae of, 1097
 visceral portion of, 1086
- Permanent cartilage, 14**
 choanae, 81
 kidney, 152
 teeth, 1055
 development of, 1063
- Peroneal anastomotic nerve, 924**
 artery, 667
 peculiarities of, 668
 nerve, common, 924
 applied anatomy of, 928
 deep, 925
 superficial, 925
 retinacula, 535
 tubercle, 332
 veins, 698
- Peroneus brevis, 534**
 longus, 534
 tertius, 520
- Perpendicular fasciculus, 829**
 line of ulna, 285
- Pes or base of cerebral peduncle, 788**
 cavus, 422
 hippocampi, 810
 planus or flat-foot, 422
- Petit, canal of, 965**
 triangle of, 480
- Petro-occipital fissure, 254**
- Petrosal nerve, deep, 858, 931**
 external, 932
 greater superficial, 858, 860
 smaller superficial, 886, 991
 process, 198
 sinus, inferior, 676, 686
 superior, 686
 sulci, inferior, 196
- Petrosphenoidal fissure, 244**
- Petrosquamous sinus, 682**
 suture, 204, 206, 209
- Petrotymppanic fissure, 204, 243, 965**
- Petrous ganglion, 875**
 portion of temporal bone, 206
- Peyer's glands, 1113**
- Phalangeal processes of Corti's rods, 1002**
 of Deiters' cells, 1003
- Phalanges of cochlea, 1003**
 digitorum manus, 296
 pedis, 337
 of foot, 337
 ossification of, 339
 of hand, 296
 applied anatomy of, 298
 ossification of, 297
- Phallus, 154**
- Pharyngeal aponeurosis, 1078**
 artery, ascending, 581
 applied anatomy of, 581
 branch of internal maxillary artery, 590
 bursa, 1077
 groove, 77
 nerve, from sphenopalatine ganglion, 860
 nerves, from glossopharyngeal, 876
 from vagus, 879
 ostium of auditory tube, 1076
 plexus of nerves, 876, 879, 932
 pouches, 77
 recess, 1077
 tonsil, 1077
 tubercle, 196, 243
 veins, 677
 venous plexus, 677
- Pharyngobasilar fascia, 1077**
- Pharyngopalatine arch, 1072**
- Pharyngopalatinus, 1075**
- Pharynx, 1076**
 applied anatomy of, 1079
 laryngeal part of, 1077
 lymphatic vessels of, 718
 muscles of, 1078
 nasal part of, 1076
 oral part of, 1077
 structure of, 1077
- Philtrum, 432, 1046**
- Phrenic arteries, inferior, 641**
 superior, 629
 ganglion, 894
 nerve, 894
 applied anatomy of, 895
 plexus of nerves, 939
 veins, inferior, 703
 superior, 691
- Phrenicocolic ligament, 1096, 1118**
- Phrenicocostal sinus, 1033**
- Phrenicocolic ligament, 1091, 1201**
- Phrenicopericardiac ligament, right, 702**
- Phthirical chest, 152**
- Pia mater, cerebral, 845**
 spinal, 845
- Pigeon-breast, 192**
- Pigment, 13**
 applied anatomy of, 14
 of iris, 959
 of skin, 1010
- Pigmentary layer of retina, 961**
- Pigmented connective-tissue cells, 13**
 epithelial cells, 13
- Piles, 700**
- Pillars of Corti, 1002**
 of fauces, 1072
 of fornix, 824, 825
 of subcutaneous inguinal ring, 458
- Pineal body, 798**
 applied anatomy of, 798
 development of, 95
 structure of, 798
 recess, 803
- Pinna, 979**
 development of, 109
- Piriformis muscle, 523**
 fascia of, 467
- Pirogoff's amputation, 340**
- Placenta, 66**
 basal plate of, 66
 circulation through, 67, 566
 cotyledons of, 66, 68
 fibrinoid substance of, 66
 fetal portion of, 66
 marginal sinus of, 67
 maternal portion of, 66
 previa, 68
 separation of, 68
 septa of, 66
- Plain muscle, 32**
- Plane, intertubercular, 1084**
 transpyloric, 1084
- Plantar aponeurosis, 537**
 arch, 668
 applied anatomy of, 669
 artery, medial or internal, 668
 deep, 666
 lateral or external, 668
 calcaneocuboid ligament, 416
 calcaneonavicular ligament, 416
 cutaneous venous arch, 695
 network, 695
 digital veins, 698
 interosseus, first, 539
 ligament, long, 416
 metatarsal arteries, 669
 nerve, lateral, 923
 medial, 923
 veins, 698
 venous arch, cutaneous, 695
 deep, 698
 network, cutaneous, 695
- Plantaris, 531**
- Planum nuchale, 193**
 occipitale, 193
- Plasma cells, 9**
- Plasma or liquor sanguinis, 26**
- Plate or plates—**
 auditory, 106
 basal of placenta, 66
 meatal, 108
 orbital of frontal bone, 215
 occipital, 73
 sternal, 72, 184
 urethral, 154
- Platelets of blood, 29**
- Platysma muscle, 437**
- Pleura, 1031**
 applied anatomy of, 1034
 cavity of, 1031
 costal, 1032
 cupula of, 1033
 diaphragmatic, 1033
 lymphatic vessels of, 739
 mediastinal, 1033
 parietal, 1031
 pulmonary, 1031
 structure of, 1034
 surface markings of, 1239
 vessels and nerves of, 1034
- Pleurisy, 1034**
- Pleuropericardial membrane, 145**

Pleuroperitoneal membrane, 145
 Plexiform layers of retina, 962, 963
 Plexus or plexuses—
 abdominal aortic, 939
 aortic thoracalis, 933
 Auerbach's, 1114
 basilar, 686
 brachial, 895
 cardiac, 937
 carotid, internal, 931
 of veins, 678
 cavernous, 931
 cervical, 891
 posterior, 888
 chorioid of fourth ventricle, 795
 of lateral ventricle, 826
 of third ventricle, 802
 coccygeal, 927
 coeliac, 937
 of cornea, annular, 955
 intra-epithelial, 955
 subepithelial, 955
 coronary, 937
 of Exner, 829
 gastric, anterior, 881
 inferior, 939
 posterior, 881
 superior, 939
 great, of sympathetic, 937
 hæmorrhoidal, middle, 940
 superior, 940
 venous, 700
 hepatic, 939
 hypogastric, 940
 infraorbital, 858, 871
 interlobular, 1139
 lienal, 939
 lumbar, 911
 Meissner's, 1114
 mesenteric, inferior, 939
 superior, 939
 myenteric, 1114
 oesophageal, 878, 880
 ovarian, 939
 pampiniform, 702, 1171
 parotid, 869
 patellar, 913, 917
 pelvic, 940
 pharyngeal, 876, 879, 932
 venous, 877
 phrenic, 939
 prostatic, 940
 venous, 700
 pterygoid, 674
 pudendal, 925
 venous, 700
 pulmonary, 878, 880
 renal, 939
 sacral, 917
 solar, 937
 spermatic, 939
 splenic, 939
 of submucosa, 1114
 subpleural mediastinal, 609
 substernal, 916
 suprarenal, 939
 tympanic, 876, 991
 uterine, 940
 venous, 701
 vaginal, 940
 venous, 701
 vesical, 940
 venous, 700
 Plica fibrillata of tongue, 1065
 gubernatrix, 152

Plica lacrimalis of Hasner, 978
 semilunaris of conjunctiva, 976
 of tonsil, 1072
 sublingualis, 1052
 supratonsillar, 1072
 triangularis of tonsil, 1072
 vascularis, 152
 vesicalis transversa, 1089
 Plicæ transversales recti, 1120
 uretericæ, 1158
 Pneumothorax, 1034, 1044
 Polar bodies or polocytes, 43, 44
 Pole, embryonic, 49
 Poles of cerebral hemi-spheres, 805
 of bulb of eye, 951
 of lens, 965
 Poliomyelitis, acute anterior, 769
 Polocytes or polar bodies, 43, 44
 Polymorphonuclear leucocytes, 28
 Polyspermy, 47
 Pomum Adami, 1017
 Pons, 772
 applied anatomy of, 775
 development of, 92
 structure of, 773
 hepatitis, 1134
 Ponticulus of auricula, 981
 Pontine arteries, 608
 flexure of embryonic brain, 91
 Popliteal artery, 661
 applied anatomy of, 661
 branches of, 662
 peculiarities of, 661
 surface marking of, 1262
 fossa or space, 660
 ligament, arcuate, 402
 oblique, 402
 retinaculum of, 402
 line of tibia, 320
 lymph-glands, 721
 nerve, external, 924
 internal, 922
 surface of femur, 312
 vein, 698
 Popliteus, 531
 Pore, gustatory, 942
 Porta hepatis, 1135
 Portal canal, 1139
 obstruction, 706
 vein, 704
 applied anatomy of, 706
 development of, 122
 Porus acusticus externus, 209, 982
 internus, 207
 Postanal gut, 139
 Position of pelvis, 306
 Postaxial borders of limbs, 83
 Postconal sulcus, 809
 Postganglionic nerve-fibres, 740, 887
 Postglenoid tubercle, 204
 Postnodular fissure, 93, 777
 Postpartum hæmorrhage, 68
 Postpyramidal fissure, 777
 Posterolateral ganglionic arteries, 608
 Posteromedial ganglionic arteries, 601, 608
 Pott's fracture, 544
 Pouch of Douglas, 1067, 1186

Pouch of Prussak, 991
 of Rathke, 132
 of Scessel, 132
 Pouches, pharyngeal, 77
 Poupart's ligament, 459
 Præcuneus, 809
 Præputium clitoridis, 1192
 Pre-aortic lymph-glands, 726
 Pre-auricular point, 1196
 sulcus of ilium, 300
 Pre-axial border of limbs, 83
 Precentral sulcus, 808
 Prechordal cartilages, 74
 part of base of skull, 74
 Preclival fissure, 776
 Preganglionic nerve-fibres, 740, 887
 Prelaryngeal lymph-glands, 715
 Premature synostosis, 25
 Premaxilla, 229
 Premolar teeth, 1057
 Pre-occipital notch, 806
 Prepuce of clitoria, 1192
 of penis, 1174
 development of, 154
 Preputial glands, 1174
 sac, 1174
 Prepyramidal fissure, 777
 Pretracheal fascia, 437
 lymph-glands, 715
 Prevertebral fascia, 436
 Pregnancy, abdominal, 47
 tubal, 47
 Presbyopia, 968
 Preseptal space, 908
 Pressure æpiphyses, 24
 Prickle-cells, 7, 1009
 Primary areolæ of bone, 22
 curves of vertebral column, 179
 labial groove, 129
 lamellæ, 19
 meatus, 108
 oocytes, 41
 spermatocytes, 45
 Primitive aorta, 111
 choana, 80
 costal arches, 71
 groove, 50
 jugular veins, 123
 mesoderm, 50
 ova, 150
 palate, 80
 segments, 55, 69
 sheath of nerve-fibre, 38, 39
 streak, 50
 urogenital ostium, 155
 Princeps cervicis artery, 585
 pollicis artery, 623
 Principal cavity of right atrium, 559
 Prismata adamantina, 1059
 Prisms, enamel, 1059
 Procerus, 429
 Process or processes—
 accessory, of vertebra, 170
 alar, of ethmoidal bone, 217
 alveolar, of maxilla, 228
 anterior, of malleus, 969
 articular, of vertebra, 108
 axis-cylinder, of nerve-cell, 35
 caudate, of liver, 1136
 ciliary, 957
 clinoid, anterior, 201, 252
 middle, 197, 254
 posterior, 195, 254
 condyloid, of mandible, 237

Process or processes (*cont.*)

- coracoid, 269
 coronoid, of mandible, 237
 of ulna, 284
 costal, of a cervical vertebra, 164
 descending, of lacrimal bone, 221
 of dura mater, 840
 ethmoidal, of inferior nasal concha, 220
 frontal, of maxilla, 227
 frontonasal, 79
 frontosphenoidal, of zygomatic bone, 234
 globular, 80
 infraorbital, of zygomatic bone, 234
 intrajugular, 196
 jugular, 196, 244
 lacrimal, of inferior nasal concha, 220
 lateral, of malleus, 989
 lateral nasal, 79
 lenticular, of incus, 989
 mamillary, of vertebrae, 170
 mastoid, 205
 maxillary, of foetus, 78, 80
 of inferior nasal concha, 220
 of palatine bone, 232
 muscular, of arytenoid, 1018
 nasal, of foetus, 79
 of frontal bone, 214
 odontoid, of axis or epistropheus, 165
 orbital, of palatine bone, 232
 of zygomatic bone, 234
 palatine, of foetus, 80
 of maxilla, 228
 papillary, of liver, 1136
 paramastoid, 196
 petrosal, 198
 phalangeal, of Corti's rods, 1002
 of Deiters' cells, 1003
 protoplasmic, of nerve-cells, 36
 pterygoid, of sphenoidal bone, 201
 pyramidal, of palatine bone, 232, 243
 sphenoidal, of palatine bone, 232
 of septal cartilage of nose, 944
 spinous, of ilium, 301
 of vertebrae, 162
 styloid, of fibula, 322
 of radius, 283
 of temporal bone, 210, 243
 of ulna, 286
 supracondylar, 277*
 temporal, of zygomatic bone, 234
 transverse, of vertebrae, 162
 trochlear, of calcaneus, 332
 uncinate, of ethmoid, 219
 of pancreas, 1128
 vaginal, of sphenoid, 199, 201
 vermiform, 1116
 vocal, of arytenoid, 1018
 xiphoid, 184
 zygomatic, of frontal, 214
 of maxilla, 227
 of temporal bone, 203
- Processus brevis of malleus, 988
 gracilis of malleus, 989
 tubarius, 201
 Proctodæum, 139
 Prodentine, 1062
 Profunda artery, inferior, 619
 superior, 619
 brachii artery, 619
 cervicalis artery, 611
 femoris artery, 658
 vein, 698
 linguae artery, 582
 Progressive facial hemiatrophy, 941
 Projection fibres of cerebral hemispheres, 828
 of cerebellum, 778
 Prominence of facial canal, 986
 laryngeal, 1017
 Promontory of sacrum, 173
 of tympanic cavity, 986
 Pronator quadratus, 495
 teres, 491
 applied anatomy of, 492
 Pronephric, duct, 146
 Pronephros, 146
 Pronucleus, female, 43
 male, 48
 Pro-otic centre of temporal bone, 210
 Proper fasciculus, anterior, 755
 lateral, 756
 Prosencephalon, 53, 93, 793
 Prostate, 1176
 applied anatomy of, 1177
 development of, 153
 isthmus of, 1176
 lobes of, 1176
 lymphatic vessels of, 734
 structure of, 1176
 vessel and nerves of, 1177
 Prostatectomy, 1178
 Prostatic ducts, orifices of, 1161
 plexus, 700
 of nerves, 940
 portion of urethra, 1161
 sinus, 1161
 utricle, 1161
 veins, 700
 Prosthion, 260
 Protoplasm, 1
 Protoplasmic processes of nerve-cells, 36
 Protuberance, mental, 235
 occipital, external, 193, 248
 internal, 194
 Prussak, pouch of, 991
 Psalterium, 824
 Pseudonucleoli, 2
 Pseudopodium, 29
 Psoas abscess, 515
 major muscle, 513
 applied anatomy of, 515
 fascia covering, 513
 minor muscle, 514
 Pterion, 261
 ossicle, 224
 Pterotic centre of temporal bone, 210
 Pterygoid canal, 201, 243
 artery of, 590, 596
 nerve, of 858
 fissure, 201
 fossa, 201
 fovea, 237
 hamulus, 201, 243
 lamina, medial, 201
- Pterygoid lamina, lateral, 201
 muscles, 434
 plexus of veins, 674
 processes of sphenoid, 201
 Pterygoideus externus, 434
 internus, 434
 Pterygomandibular raphe, 431
 Pterygomaxillary fissure, 247
 Pterygopalatine canal, 225, 231
 fossa, 247
 sulcus, 201, 231
 Pterygospinous ligament, 203
 435
 Ptosis, 978
 Pubic arch, 306
 ligaments, 390, 391
 symphysis, 390
 tubercle or spine, 302
 vein, 699
 Puboanalis, 471*
 Pubocapsular ligament, 395
 Pubococcygeus, 471
 Puborectalis, 471
 Pubovesicales, 1157, 1159
 Pudendal artery, accessory, 649
 deep external, 657
 superficial, 657
 internal, in female, 647
 in male, 646
 cleft or rima, 1191
 nerve, 926
 inferior, 920
 plexus, nervous, 925
 venous, 700
 veins, internal, 700
 Pudendum, 1191
 Pudic nerve, 926
 vein, internal, 700
 Pulmonary artery, 569
 applied anatomy of, 570
 atresia of, 570
 orifice of, in right ventricle, 558
 stenosis, of 570
 circulation, 545
 emphysema, 192
 ligament, 1033
 lymph-glands, 737
 pleura, 1031
 plexuses, 878, 880
 ridge, 144
 semilunar valves, 559
 veins, 670
 openings of, in left atrium, 560
 Pulmones, 1037
 Pulp, dental, 1057
 enamel, 1061
 splenic, 1202
 Pulp-cavity of teeth, 1057
 Pulvinar, 794
 Puncta lacrimalia, 977
 vasculosa, 813
 Pupil, 955, 958
 congenital atresia of, 105
 Pupillary membrane, 105, 980
 Purkinje, cells of, 781
 fibres of, 34
 Purple, visual, 14, 960
 Putamen, 820
 Pyæmia, 25
 Pylephlebitis, suppurative or septic, 706
 Pyloric antrum, 1099
 artery, 634
 glands, 1104
 orifice of stomach, 1098

Pyloric part of stomach, 1099
valve, 1101
vein, 706
Pyopneumothorax, 1034
Pyorrhea alveolaris, 1048
Pyosalpinx, 1183
Pyramid of cerebellum, 778
 of medulla oblongata, 762
 of temporal bone, 206
 of vestibule, 903
Pyramidal cells of cerebral cortex, 829
 • **decussation**, 762
 eminence of tympanic cavity, 987
 lobe of thyroid gland, 1196
 process of palatine bone, 232, 243
 tract, crossed, 755
 direct, 754
Pyramidalis abdominis, 464
nasi, 429
Pyramids, renal, 1147

Quadrangular lobules of cerebellum, 776
Quadrate ligament, 376
 lobe of cerebellum, 809
 of liver, 1135
Quadratus femoris, 525
 labii inferioris, 430
 superioris, 430
 humborum, 467
 fascia covering, 466
 plantæ, 539
Quadriceps femoris, 518
Quadrigeminal bodies, 791

Radial artery, 620
 applied anatomy of, 622
 branches of, 622
 peculiarities of, 622
 surface marking of, 1253
 collateral ligament of elbow-joint, 376
 of wrist-joint, 382
 fibres of cerebral cortex, 831
 fossa, 277
 nerve, 904
 applied anatomy of, 907
 deep branch, 906
 superficial branch, 905
 notch of ulna, 284
 recurrent artery, 622
 tuberosity, 282
Radiate ligament, 359
 sternocostal ligaments, 361
Radii lentis, 965
Radiocarpal articulation, 380
 applied anatomy of, 384
 movements of, 384
 surface form of, 1246, 1250
 ligament, dorsal, 381
 volar, 381
Radio-ulnar articulation, distal, 377
 movements of, 378
 proximal, 376
 movements of, 378
 union, middle, 376
Radius, 279
 applied anatomy of, 287
 oblique line of, 282
 ossification of, 283
 sigmoid cavity of, 282
 structure of, 283
 surface anatomy of, 1245
 tuberosity of, 282

Radius, ulnar notch of, 282
Rami communicantes, 740, 887, 928, 930
 dorsales linguae, 582
Ramus colli, 871
 of mandible, 236
 of ischium, inferior, 302
 superior, 301
 marginalis mandibulae, 871
 of os pubis, inferior, 303
 superior, 302
Ranine artery, 582
vein, 677
Ranvier, crosses of, 39
 nodes of, 39
Raphe, anococcygeal, 470, 472
 lateral palpebral, 429
 of medulla oblongata, 762
 of palate, 1048
 pterygomandibular, 431
 of scrotum, 1171
Rathke, pouch of, 132
Rays, medullary of kidney, 1147
Recess, epitympanic, 206, 984
 lienal, 1092
 nasopalatine, 946
 omental, inferior, 1092
 middle, 1092
 superior, 1092
 optic, 803
 pharyngeal, 1077
 pineal, 803
 sphenocethmoidal, 257, 945
 tubotympanic, 108
Recesses, peritoneal, 1097
 of Tröltsch, 991
Recessus ellipticus, 903
 infundibuli, 802
 pinealis, 803
 sacciformis, 377
 sphaericus, 993
 suprapinealis, 803
Rectal ampulla, 1120
 columns of Morgagni, 1122
 layer of pelvic fascia, 469
 sinus, 1122
Rectococcygeal muscles, 1122
Recto-uterine excavation, 1087
 1186
 folds, 1186
Rectovesical excavation, 1087
 folds, 1089
 layer of pelvic fascia, 469
Rectovesicales, 1157
Rectum, 1120
 ampulla of, 1120
 anal part of, 1121
 applied anatomy of, 1127
 development of, 139
 flexures of, 1120
 Houston's valves of, 1120
 lymphatic vessels of, 731
 relations of, 1121
 transverse folds of, 1120
Rectus abdominis, 463
 sheath of, 463
 capitis anterior, 443
 anticus major, 442
 minor, 443
 lateralis, 443
 posterior major, 449
 minor, 449
 femoris, 518
 applied anatomy of, 519
 muscles of eyeball, 970
Recurrent artery, interosseous, 625

Recurrent artery, radial, 622
 tibial, anterior, 665
 posterior, 665
 ulnar, anterior, 625
 posterior, 625
 branches from deep volar arch, 623
 nerve (laryngeal), 880
Red blood-corpuscles, 26
 origin of, 27
 nucleus, 789
Reflected inguinal ligament, 460
Reflex actions, abnormalities of, 838
Reflex, ciliospinal, 838
Reflexes, deep or tendon, 838
 organic, 838
 superficial or skin, 838
Refracting media of eye, 964
Region, anterior, of medulla oblongata, 762
 lateral, 763
 posterior, 763
Regions of abdomen, 1084
Reid's base-line, 1213
Reil, island of, 811
Reissner, vestibular membrane of, 999
Remak, fibres of, 40
Renal arteries, 640
 • calyces, 1145
 columns, 1147
 fascia, 1146
 impression, 1136
 pelvis, 1146
 plexus, 939
 pyramids, 1147
 sinus, 1145
 tubules, 1147
 veins, 703
 vessels, afferent and efferent, 1150
Renes, 1143
Reproduction of cells, 2
 by direct division, 2
 by indirect division, 2
Resection of rib, 192
Respiration, mechanism of, 456
Respiratory apparatus, 1016
 development of, 142
 region of nasal cavities, 945, 947
Restiform bodies, 769, 779
Resting stage of cell, 2
Rete canalis hypoglossi, 686
 foraminis ovalia, 687
 testis, 1167
Reticular lamina, 1003
 layer of skin, 1010
 tissue, 12
Reticularis alba, 771
 grisea, 771
Reticulum, stellate, 1061
Retiform tissue, 12
Retina, 960
 applied anatomy of, 968
 central artery of, 597
 development of, 102
 fovea centralis of, 961, 964
 layers of, 961
 macula lutea of, 961, 964
 membrana limitans interna, 963
 externa, 964
 ora serrata of, 960
 structure of, 961
 supporting framework of, 963

- Retinacula, of hip-joint, 394
 patellar, 400
 peroneal, 535
 Retinaculum of arcuate popliteal ligament, 402
 Retro-aortic lymph-glands, 726
 Retroaëcal fossa, 1098
 Retroglanular sulcus of penis, 1174
 Retropharyngeal abscess, 437, 1079
 lymph-glands, 714
 space, 437
 Retropubic pad, 1155
 Retzius, space of, 1160
 Rhinal fissure, external, 96
 Rhinencephalon, 96, 812
 Rhodopsin, or visual purple, 14, 960
 Rhombencephalon, 53, 91, 761
 Rhombic grooves, 92
 lip, 92
 Rhinion, 260
 Rhinoid fossa, 785
 impression, 272
 ligament, 366
 Rhomboideus major, 480
 minor, 480
 Ribs, 185
 applied anatomy of, 191
 articulations of, 358
 cervical, 166, 192
 common characteristics of, 186
 development of, 71
 false, 186
 floating, or vertebral, 186
 fracture of, 191
 ossification of, 189
 peculiar, 188
 resection of, 192
 structure of, 189
 true, 185
 vertebral, or floating, 186, 365
 vertebrochondral, 186, 364
 Rickets, 192, 309
 Rickety rosary, 192
 Rider's bone, 424, 522
 Ridge, basal, of tooth, 1056
 ganglion, 53, 88
 genital, 140
 lateral supracondylar, 276
 medial supracondylar, 276
 pulmonary, 144
 trapezoid or oblique, 271
 Ridges, bicipital, 274
 Riedel's lobe of the liver, 1142
 Right atrioventricular orifice, 558
 atrium of heart, 555
 margin of heart, 554
 ventricle of heart, 558
 Rima glottidis, 1024
 of mouth, 1046
 palpebrarum, 973
 pudendal, 1191
 Ring, abdominal inguinal, 465
 external abdominal, 458
 femoral, 654
 internal abdominal, 465
 subcutaneous inguinal, 458
 tympanic, 210
 Rings, fibrous, of heart, 562
 Riolan, muscle of, 428
 Ripening of ovum, 43
 Risorius, 432
 Rivinus, ducts of, 1062
 notch of, 985
 Rod-bipolars of retina, 962
 Rod-granules of retina, 963
 Rods and cones, layer of, 963
 Rods of Corti, 1002
 of retina, 963
 Rolando, fissure of, 806
 substantia gelatinosa of, 749
 tubercle of, 764
 Roller, nucleus of, 771
 Roof-plate, 86
 Root of penis, 1174
 Root-sheaths of hair, 1013
 Roots of lungs, 1041
 of spinal nerves, 758
 of teeth, 1055
 of vertebral arches, 161
 of zygomatous process, 203
 Rosenmüller, fossa of, 79, 1077
 lymph-gland of, 723
 organ of, 147, 1181
 Rostrum of corpus callosum, 814
 sphenoidal, 199
 Rotation, movement of, 345
 Rotatores muscles, 448
 Round ligament of liver, 1137
 of uterus, 1186
 Rubrospinal fasciculus (Monakow), 755
 Ruffini, corpuscles of, 1007
 Rust-coloured layer of cerebellar cortex, 781
 Sac, dental, 1061
 greater, of peritoneum, 1086
 lacrimal, 977
 lesser, of peritoneum, 1088
 preputial, 1174
 Sacculated bladder, 1160
 Sacculæ, laryngeal, 1023
 of vestibule, 997
 structure of, 998
 Saccus vaginalis, 152
 endolymphatic, 997
 Sacral arteries, lateral, 649
 artery, middle, 642
 canal, 175
 cornua, 172
 crest, medial, 172
 crests, articular, 172
 lateral, 172
 flexure of rectum, 1120
 foramina, 171, 172
 groove, 172
 group of preganglionic fibres, 930
 hiatus, 172
 lymph-glands, 725
 nerves, anterior divisions of, 917
 posterior divisions of, 890
 nucleus of medulla spinalis, 752
 plexus, 917
 applied anatomy of, 927
 tuberosity, 173
 veins, lateral, 700
 middle, 701
 Sacrococcygeal ligaments, 352, 353
 Sacrogenital folds, 1089, 1186
 Sacro-iliac articulation, 338
 ligaments, 388, 389
 Sacrosciatic ligament, great, 389
 small, 390
 Sacrospinalis, 445
 Sacrospinous ligament, 390
 Sacrotuberous ligament, 389
 Sacrovertebral angle, 171
 Sacrum, 171
 ala of, 173
 apex of, 175
 auricular surface of, 173
 base of, 173
 differences between male and female, 175
 foramina of, 171, 173
 inferior lateral angle, 173
 ossification of, 178
 promontory of, 173
 structure of, 175
 variations of, 175
 Saddle articulation, 345
 Sagittal fossæ, of liver, 1134
 sinus, inferior, 681
 superior, 680
 applied anatomy of, 681
 sulcus, 194, 211, 215
 suture, 212, 241
 Salivary glands, 1049
 parotid, 1049
 sublingual, 1052
 submaxillary, 1051
 development of, 130
 structure of, 1052
 Salpingitis, 1183
 Salpingopalatine fold, 1076
 Salvingopharyngeal fold, 1076
 Salpingopharyngeus, 1079
 Santorini, cartilages of, 1018
 duct of, 1132
 Saphenous nerve, 916
 external, 923
 opening, 516
 vein, accessory, 696
 great, 695
 small, 696
 applied anatomy of, 697
 Sarcolemma, 30
 Sarcomere, 31
 Sarcoplasma, 31
 Sarcostyles, 31
 Sarcous element of muscle, 32
 Sartorius, 517
 Sauroid blood-cells, 110
 Scala media, 998
 tympani, 996
 vestibuli, 996
 Scalene tubercle, 188
 Scalenus anterior, 444
 medius, 444
 posterior, 444
 Scalp, applied anatomy of, 427
 lymphatic vessels of, 716
 Scapha, 979
 Scaphoid fossa, 201, 243
 Scapula, 266
 acromion of, 268
 applied anatomy of, 271
 coracoid process of, 269
 glenoid cavity of, 269
 inferior transverse ligament of, 269
 superior, 368
 ligaments of, 368
 ossification of, 270
 spine of, 268
 structure of, 270
 surface anatomy of, 1245
 Scapulae alata, 271
 Scapular artery, posterior, 611
 transverse, 610
 Circumflex artery, 616
 nerve, dorsal, 896

Scapular notch, 268
 great, 260
 Scapulo-shoulder of hair, 1012, 1014
 Scarpa, fascia of, 457
 foramina of, 228, 243
 ganglion of, 1004
 triangle of, 664
 Schlemm, canal of, 952
 Schreger, lines of, 1059
 Schwann, white substance of, 38, 39
 Sciatic artery, 649
 foramen, greater, 390
 lesser, 390
 nerve, 920
 applied anatomy of, 927
 small, 920
 notch, greater, 301
 lesser, 301
 veins, 700
 Sclera, 951
 applied anatomy of, 967
 structure of, 952
 Scleral spur, 953
 Sclerogenous layer, 69
 Sclerocorneal junction, 952
 Sclerotomy, 69
 Scrotal arteries, posterior, 647
 hernia, 1125
 nerves, posterior, 926
 Scrotum, 1171
 applied anatomy of, 1172
 dartos tunic of, 1171
 raphe of, 1171
 skin of, 1171
 vessels and nerves of, 1172
 Sebaceous cysts, 428
 glands, 1014
 development of, 85
 Second cervical nerve, anterior
 division, 891
 posterior division, 888
 cervical vertebra, 165
 cuneiform bone, 333
 ossification of, 338
 metacarpal bone, 295
 metatarsal bone, 337
 rib, 180
 Secondary areolæ of bone, 23
 curves of vertebral column, 179
 dentine, 1059
 labial groove, 129
 lamellæ, 19
 meatus, 108
 oocyte, 44
 sensory fasciculus, 756
 spermatocytes, 45
 spiral lamina, 996
 tympanic membrane, 986, 996
 Secretions, internal, 1195
 Sessal's pouch, 132
 Segments, internodal, 39
 of Lantermann, 39
 medullary, 39
 Segmental arteries, dorsal, 121
 lateral, 121
 ventral, 121
 Segmentation of cells, 41
 cavity, 49
 of fertilised ovum, 48
 nucleus, 48
 Segments, primitive, 55, 69
 spinal, 746
 Sella turcica, 197, 253
 Semicapalis m. tensoris tym-
 pani, 209, 987
 tube auditiva, 209

Semicircular canals, 904
 ducts, 907
 structure of, 998
 Semilunar arteries, 596
 bone, 291
 fibrocartilages of knee, 404
 ganglion of coeliac plexus, 938
 of trigeminal nerve, 853
 lobule, inferior, 778
 superior, 777
 notch of ulna, 284
 valves, aortic, 561
 pulmonary, 559
 Semimembranosus, 527
 Seminal vesicles, 1169
 Semispinalis capitis, 448
 cervicis, 447
 dorsi, 447
 Semitendinosus, 527
 Sensations, general, peripheral
 terminations of nerves of, 1005
 Senses, organs of, 942
 development of, 85
 special, peripheral organs of, 942
 Sensory decussation, 767, 836
 neurons, intermediate, lower
 and upper, 836
 paralysis, 838
 tract, 836
 Separation of placenta, 68
 Septa, intersegmental, 69
 placental, 66
 Septula testis, 1166
 Septum, aortic, 117
 of bulbus cordis, 117
 canalis musculotubarii, 209, 988
 crural, 654
 femoral, 654
 inferior of heart, 117
 intermedium, 115
 lateral intermuscular, of arm, 488
 medial intermuscular, of arm, 488
 mobile nasi, 944
 nasi, 256
 orbital, 975
 pectiniforme, 1173
 pellucidum, 826
 cavity of, 826
 of penis, 1173
 primum, 115
 secundum, 115, 568
 spurium, 115
 subarachnoid, 844
 of tongue, 1070
 transversum of fœtus, 113, 143
 of semicircular duct, 998
 of truncus arteriosus, 117
 urorectal, 139
 ventricular, 117, 562
 Sequesterum, 25
 Serosa, or false amnion, 61*
 Serous glands of tongue, 1070
 pericardium, 561
 Serratus, anterior, 484
 applied anatomy of, 485
 magnus, 484
 posterior inferior, 451
 superior, 451
 Sertoli, supporting cells of, 1166
 Sesamoid bones, 349
 Seventh cervical vertebra, 166, 178

Shaft of hair, 1012, 1014
 Sheath of arteries, 546
 carotid, 436
 dental, of Neumann, 1058
 epithelial, 1063
 femoral, 653
 medullary, 39
 mitochondrial, of spermat-
 oöon, 45
 nucleated, of Schwann, 38
 primitive, 38, 39
 of rectus abdominis, 443
 Sheaths, fibrous, of flexor ten-
 dons of fingers, 493
 of toes, 539
 mucous, 343
 of tendons around ankle, 536
 on back of wrist, 503
 on front of wrist, 501
 Shin, 320
 Shingles, 760
 Short bones, 160
 fibular collateral ligament of
 knee-joint, 402
 gastric veins, 705
 Shoulder, muscles of, 485
 Shoulder-blade, 266
 Shoulder girdle, 265
 joint, 369
 applied anatomy of, 372
 bursa in relation to, 370
 movements of, 371
 vessels and nerves of, 371
 Sibson's fascia, 1033
 Sight, organ of, 951
 Sigmoid arteries, 638
 cavity of radius, 282
 greater, of ulna, 284
 lesser, of ulna, 285
 colon, 1118
 mesocolon, 1096
 sinus, 682
 Simple squamous epithelium, 4
 Sino-atrial node, 564
 Sinus or sinuses—
 accessory of nose, 949
 aortic, 561
 cervicalis, 78
 confluence of, 194
 coronary, 556, 671
 valve of, 556, 671
 costomediastinal, 1034
 cranial, 108*
 of dura mater, 680
 basilar plexus, 680
 cavernous, 683
 circular, 680
 confluence of, 683
 intercavernous, 685
 lateral, 681
 longitudinal, inferior, 681
 superior, 680
 meningeal, middle, 686
 occipital, 682
 petrosal, inferior, 686
 superior, 686
 petrosquamous, 682
 sagittal, inferior, 681
 superior, 680
 sigmoid, 682
 sphenoparietal, 683
 straight, 681
 transverse, 681
 of epididymis, 1165
 of external jugular vein, 675
 frontal, 216, 949
 intercavernous, 685

Sinus or sinuses (*cont.*)

- lateral, 681
- marginal, of placenta, 67
- maxillary, 226, 950
- of Morgagni, 1078
- occipital, 682
- of pericardium, oblique, 552
- transverse, 552
- petrosal, inferior, 686
- superior, 686
- petrosquamous, 682
- phenicocostal, 1033
- prostatic, 1161
- piriformis, 1077
- rectal, 1122
- renal, 1147
- sagittal, inferior, 681
- superior, 680
- septum, 115
- sigmoid, 682
- sphenoidal, 198, 949
- sphenoparietal, 683
- straight, 681
- tarsi, 329, 331
- tonsillaris, 78, 1072
- torcular Herophili, 683
- transverse, 681
- urogenital, 153
- of Valsalva, 559, 561
- venarum, 555
- venosus, 113
- development of, 113
- scleræ, 952

Sinusoids, 122, 189, 548, 1139

Skein, or spiræm, 2, 3

Skeleton, 160

appendicular part of, 160

axial part of, 160

development of, 69

Skene's ducts, 153

Skin, 1008

appendages of, 1011

hairs, 1012

nails, 1011

sebaceous glands, 1014

sudoriferous or sweat glands, 1014

arteries of, 1011

corium or cutis vera, 1010

development of, 84

epidermis or cuticle, 1008

epitrichium, 84

finger-prints of, 1008

nerves of, 1011

papillary layer of, 1011

reflexes, 838

reticular layer of, 1010

stratum corneum, 1010

germinativum, 84, 1009

granulosum, 1009

lucidum, 1010

mucosum, 1009

Skull, 193

applied anatomy of, 262

bones of, 193

capacity of, 200

chordal part of, 74

craniology, 260

deformities of, 264

development of, 72

differences in, due to age, 258

exterior of, 241

fossa, anterior, 252

middle, 252

posterior, 254

fractures of, 263

interior of, 252

norma basalis, 241

Skull, norma frontalis, 248

lateralis, 244

occipitalis, 247

verticalis, 241

prechordal part of, 74

sexual differences in, 259

surface anatomy of, 1209

tables of, 161, 196

upper surface of base of, 252

Skull-cap, inner surface of, 252

Sleep palsies, 906

Slightly movable joints, 344

Small intestine, 1105

duodenum, 1106

ileum, 1108

jejunum, 1108

aggregated lymphatic nodules of, 1113

circular folds of, 1110

glands of, 1112

lymphatic vessels of, 731

Meckel's diverticulum of, 57, 1100

mesenteric part of, 1108

Peyer's glands of, 1113

solitary lymphatic nodules of, 1112

structure of, 1100

valvulae conniventes of, 1100

vessels and nerves of, 1113

villi of, 1111

cardiac vein, 672

saphenous vein, 696

sciatic nerve, 929

wings of sphenoid, 200

Smaller occipital nerve, 891

superficial petrosal nerve, 991

Smallest cardiac veins, 672

Smegma præputii, 1174

Smell, organ of, 943

Soft palate, 1048

aponeurosis of, 1073

arches or pillars of, 1072

muscles of, 1074

paralysis of, 1043

Solar plexus, 337

Sole of foot, muscles of, first

layer, 538

fourth layer, 540

second layer, 539

third layer, 539

Soleus, 530

Solitary cells of medulla

spinalis, 752

lymphatic nodules, 1112, 1123

Somatic cells, 41

fibres of spinal nerve, 887

layer of mesoderm, 52

Somatopleure, 53

Space of Burns, 436

epidural, 841

of Nuel, 1003

popliteal, 660

preseptal, 968

retropharyngeal, 437

Space of Retzius, 1160

subdural, 842

suprasternal, 436

Spaces of angle of iris, 955

cavernous, of penis, 1175

corneal, 954

of Fontana, 955

intercostal, 186

interglobular, 1059

medullary, 23

Spasmodic torticollis, 439

Spatia zonularia, 965

Special dental germs, 1060

end-organs of nerves, 1005

types of cerebral cortex, 831

Spermatic artery, external, 932

Spermatic cord, 1170

coverings of, 1171

structure of, 1171

fascia, external, 459, 1171

nerve, external, 913

plexus of nerves, 939

applied anatomy of, 939

veins, 702

applied anatomy of, 703

Spermatis, 45, 1166

Spermatoblasts, 1166

Spermatocoele, 1168

Spermatocytes, 45, 1166

Spermatogonia, 45, 1166

Spermatozoon, 44, 1166

acrosome of, 44

anterior centriole of, 44

axial filament of, 45

body or connecting piece of, 44

head of, 44

mitochondrial sheath of, 45

neck of, 44

perforator of, 44

posterior centriole of, 44

spiral thread of, 45

tail of, 45

terminal disc or ring of, 44

Sphenothmoidal recess, 257,

945

suture, 252

Sphenofrontal suture, 245, 252

Sphenoidal air-sinuses, 198, 949

bone, 197

applied anatomy of, 203

body of, 197

great wings of, 199

ossification of, 202

pterygoid processes of, 201

small wings of, 200

conchæ, 201

crest, 198

process of palatine bone, 232

of septal cartilage of nose, 944

rostrum, 199

Sphenomandibular ligament, 347

Sphenomaxillary fissure, 246

fossa, 247

Sphenopalatine artery, 590

foramen, 232

ganglion, 858

nerves, 857

notch, 232, 233

Sphenoparietal sinus, 683

suture, 245

Sphenopetrosal suture, 252

Sphenosquamosal suture, 245

Sphere, attraction, 2

Sphincter ani externus, 472

internus, 473

pupilla, 957

recti, 471

urethra membranacea in

female, 477

in male, 476

vagina, 476, 1190

vesica, 1159

Spigelian lobe of liver, 1135

Spina angularis, 199

biida, 181

INDEX

- Spina helix*, 990
trochlearis, 215
vestibuli, 115
Spinal accessory nerve, 881
anesthesia, 844
arteries, 807
column, 161, 179
cord, 745
dura mater, 841
ganglia, 746, 885
 structure of, 885
meningitis, acute, 844
myelitis, 760
nerves, 885
 anterior divisions of, 890
 development of, 88
 ganglia of, 885
 posterior divisions of, 887
 roots of, 758, 885
 size and direction of, 885
 somatic fibres of, 887
 structure of, 887
 sympathetic fibres of, 887
 visceral divisions of, 90
paralysis, infantile, 760
segments, 746
Spinalis capitis, 448
 cervicis, 447
 dorsi, 447
Spindle, achromatic, 2
 aortic, 573
 neuromuscular, 1007
 neurotendinous, 1007
Spine, ethmoidal, 197
 frontal, 214
 ischial, 301
 mental, 235
 nasal, anterior, 224, 229
 posterior, 230, 243
 pubic, 302
 of scapula, 268
 suprameatal, 210, 246
 tibial, 318
 trochlear, 215, 249
Spines, iliac, 301
Spinocerebellar fasciculus, an-
 terior, 756
Spinoglenoid ligament, 369
Spino-olivary fasciculus, 769
Spinotectal fasciculus, 756
Spinohalamic fasciculus, 756
Spinous process of a vertebra,
 162
Spiral canal of modiolus, 995
 ganglion of cochlea, 1004
 organ of Corti, 1001
 thread of spermatozoon, 45
 tubule of kidney, 1147
Spirem or skein, 2, 3
Splanchnic layer of mesoderm,
 53
 nerve, greater, 934
 lesser, 934
 lowest, 934
Splanchnology, 1016
Splanchnopleure, 53
Spleen or lien, 1200
 applied anatomy of, 1204
 blood-vessels of, 1202
 development of, 141
 lymphatic vessels of, 732
 Malpighian bodies of, 1203
 structure of, 1202
 surface marking of, 1239
Spleens, accessory, 1202
Splenic centre of ossification,
 238
Splenic artery, 885
 Splenic artery, applied anatomy
 of, 636
 distribution of, 1202
 cells, 1202
 flexure of colon, 1114, 1118
 plexus, 939
 pulp, 1202
 vein, 708
 Splenium of corpus callosum, 815
 Splenius capitis, 445
 cervicis, 445
 Spongiblasts, 86
 Spongioplaem, 1
 Spot, germinal, 41, 42
 Spring ligament, 417
 Spur, or cog-tooth, of malleus,
 889
 scleral, 963
 Squama, frontal, 213
 occipital, 193
 temporal, 203
 Squamosal suture, 204, 245
 Squamous epithelium, 4
 Stahr, middle lymph-gland of,
 714
 Stalks, optic, 94, 102
 of thalamus, 706
 Stapedius, 991
 nerve to, 870
 Stapes, 990
 annular ligament of base of,
 990
 base, 990
 crura, 990
 development of, 108
 head, 990
 neck, 990
 Stellate cells of Kupffer, 1139
 ganglion, 935
 ligament, 359
 reticulum, 1061
 veins of kidney, 1150
 Stenosis of pulmonary orifice,
 570
 Stensen, duct of, 1050
 foramina of, 228, 243
 Stephanion, 261
 Sternal angle, 182
 branches of internal mam-
 mary artery, 609
 end of clavicle, 272
 foramen, 182
 furrow, 1227
 lymph-gland, 735
 plates, 72, 184
 Sternebrae, 182
 Sternoclavicular articulation,
 365
 applied anatomy of, 366
 movements of, 366
 surface anatomy of, 1246
 ligament, 366
 Sternocleidomastoid arteries,
 580, 585
 Sternocleidomastoideus muscle,
 438
 Sternocostal articulations, 361
 ligaments, interarticular, 363
 radiate, 362
 surface of heart, 554
 Sternohyoideus muscle, 441
 Sternopericardiac ligaments,
 461
 Sternothyroideus muscle, 441
 Sternum, 159
 applied anatomy of, 191
 body of, 182
 development of, 72
 Sternum, fracture of, 191
 manubrium of, 182
 ossification of, 184
 structure of, 184
 xiphoid process of, 184
 Stomach, 1098
 applied anatomy of, 1105
 bed, 1100
 cardiac glands of, 1104
 orifice of, 1098
 component parts of, 1100
 curvatures of, 1099
 development of, 135
 fundus of, 1100
 fundus glands of, 1104
 gastric canal, 1101
 incisura cardiaca of, 1098
 angularis of, 1099
 interior of, 1101
 lymphatic vessels of, 730
 mucous membrane of, 1103
 muscular coats of, 1102
 openings of, 1098
 position of, 1098
 pyloric antrum, 1099
 glands, 1104
 orifice, 1098
 valve, 1101
 shape and position of, 1098
 structure of, 1101
 sulcus intermedius of, 1099
 surface marking of, 1236
 surfaces of, 1099
 vessels and nerves of, 1105
 Stomodaeum, 129
 Strabismus, 852, 973
 Straight sinus, 681
 tubules of kidney, 1148
 Stratified epithelium, 6
 Stratiform fibrocartilage, 17
 Stratum cinereum, 792
 compactum of decidua, 64
 corneum, 1010
 corseal, 799
 fibrosum of articular cap-
 sule, 342
 germinativum, 1009
 granulosum, 1009
 intermedium of chorioid, 957
 of enamel organ, 1061
 laciniosum, 833
 laminis, 792
 lucidum, 1010
 mucosum, 1009
 opticum of retina, 962
 of superior colliculus, 792
 radiatum, 833
 spongiosum of decidua, 64
 synoviale of articular cap-
 sule, 342
 zonale, 792, 794
 Streak, primitive, 50
 Stria terminalis, 794, 823
 vascularis, 1000
 Striae acusticae, 786, 873
 gravidarum or albicantes,
 1233
 longitudinal, lateral and
 medial, 813
 medullares of rhomboid fossa,
 786, 873
 of olfactory tract, 813
 Striate arteries, 900
 veins, inferior, 869
 Stripe of Hensen, 1003
 Striped muscular fibres, 30
 Struma, interlobular, of 814
 ney, 1150

- Stroma, intertubular, of iris, 259
 of ovary, 1180
 Stroke of apoplexy, 834
 Styre, 978
 Styloglossus muscle, 1068
 Stylohyal part of styloid process, 210
 Stylohyoid ligament, 441
 nerve, from facial, 870
 Stylohyoides muscle, 440
 Styloid process of fibula, 322
 of radius, 283
 of temporal bone, 210, 243
 of ulna, 286
 Stylomandibular ligament, 347
 435
 Stylomastoid artery, 588
 foramen, 208, 243
 Stylopharyngeus, 1079
 Subanconeus muscle, 490
 Subarachnoid cavity, 842
 cisterna, 843
 septum, 844
 Subastragal amputation, 340
 Subcallosal gyrus, 813
 Subcardinal veins, 124
 Subclavian artery, 602
 applied anatomy of, 604
 branches of, 606
 first part of left, 602
 of right, 602
 peculiarities of, 604
 second portion of, 603
 surface anatomy of, 1211
 marking of, 1224
 third portion of, 604
 lymphatic trunks, 712
 triangle, 593
 vein, 690
 Subclavius muscle, 483
 nerve to, 897
 Subcostal angle, 191
 arteries, 630
 Subcostales muscles, 451
 Subcrureus or articularis genus muscle, 519
 Subcutaneous inguinal ring, 458
 Subdural space, 842
 Subepithelial plexus of cornea, 535
 Subinguinal lymph-glands, 22
 Sublingual artery, 582
 gland, 1062
 vessels and nerves of, 1052
 Sublobular veins, 703, 1139
 Submaxillary duct, 1052
 ganglion, 863
 gland, 1051
 vessels and nerves of, 1052
 lymph-glands, 714
 triangle, 592
 Submental artery, 584
 lymph-glands, 714
 Submucosa, plexus of, 1114
 Subnasal point, 260
 Suboccipital muscles, 449
 nerve, anterior division, 891
 posterior division, 887
 triangle, 449, 607
 Subparietal sulcus, 809
 Subperitoneal connective tissue, 466
 Subpleural mediastinal plexus, 608
 Subpubic ligament, 390
 Subpyloric lymph-glands, 727
 Subarterial plexus, 916
 Subscapular artery, 616
 fascia, 486
 fossa, 266
 nerves, 898, 899
 Subscapularis muscle, 486
 Subserous areolar tissue, 1086
 Substance, anterior perforated,
 813
 fibrinoid of placenta, 66
 posterior perforated, 787
 Substantia adamantina, 1059
 compacta, 17
 eburnea, 1059
 ferruginosa, 786
 gelatinosa centralis, 750
 of Rolando, 749
 nerve-cells in, 752
 innominate of Meynert, 822
 nigra, 789
 ossea, 1059
 propria of cornea, 954
 reticularis alba, 771
 grisea, 771
 spongiosa, 17
 Subtalar dislocation, 418
 Subthalamie tegmental region,
 794, 798
 Successional permanent teeth,
 1063
 Suctorial pad, 431
 Sudoriferous glands, 1014
 development of, 85
 Sulci and fissures of cerebral hemisphere, 805
 development of, 98
 of medulla spinalis, 747
 of medulla oblongata, 762
 Sulcus or sulci—
 anterior longitudinal of heart,
 553
 antihelical transversus, 981
 arteria vertebralis, 164
 basilaris, 773
 calcanei, 331
 carotid, 198
 central, 806
 chiasmatis, 197
 cingulate, 807
 circular, 807, 811
 circularis corneae, 953
 coronary, of heart, 553
 ethmoidal, 222
 frontal, 808
 habenulae, 794
 Harrison's, 192
 horizontal, of cerebellum,
 776
 inferior petrosal, 196
 intermedius, of stomach, 1099
 intertubercular, of humerus,
 274
 intraparietal, of Turner, 809
 lacrimalis, 225
 lateral cerebral, 806
 lateral, of cerebral peduncle,
 787
 limitans insulae, 807
 of rhomboid fossa, 785, 786
 lunatus, 807
 malleolar, 321
 malleolaris, of tympanic ring,
 210
 medial frontal, of Eberstaller,
 807
 median, of rhomboid fossa,
 785
 of tongue, 1065
 of Monroe, 94, 893
 Sulcus or sulci (*cont.*)
 mylohyoid, 236
 nervi radialis, 276
 ulnaris, 278
 occipital, lateral, 809
 transverse, 194, 809
 oculomotor, 787
 olfactory, of nasal cavity, 946
 of frontal lobe, 809
 orbital, 808
 parallel, 810
 paramedial, 808
 parolfactory, anterior, 813
 petrosal, inferior, 196
 postcentral, 809
 posterior longitudinal, of
 heart, 553
 pre-auricular, of ilium, 300
 precentral, 808
 pterygopalatine, 201, 231
 radial, 276
 retroglandular, 1174
 sagittal, 194, 211, 215
 sigmoides, 205
 spiralis externus, 1000
 internus, 1001
 subparietal, 809
 tali, 329
 temporal, 810
 terminalis, of right atrium,
 555
 of tongue, 1065
 transverse, 194
 tubae auditivae, 200, 244
 tympanic, 209, 982, 985
 valleculae, 777, 778
 Superadded permanent teeth,
 1063
 Superciliary arches, 214, 248
 Superficial anterolateral fasci-
 culus, 756
 branch of radial nerve, 905
 cervical artery, 611
 lymph-glands, 715
 muscles, 437
 epigastric artery, 657
 external pudendal artery,
 657
 iliac circumflex artery, 657
 palmar arch, 627
 peroneal nerve, 925
 petrosal nerve, greater, 858,
 869
 lesser, 876, 991
 temporal artery, 586
 applied anatomy of, 587
 vein, 674
 transverse fasciculi of hand,
 505
 volar arch, 627
 artery, 622
 Superior ganglion of glosso-
 pharyngeal nerve, 875
 laryngeal artery, 580
 nasal concha, 219
 nuchal line, 193
 orbital fissure, 200, 251, 253
 petrosal sinus, 686
 pubic ligament, 390
 sagittal sinus, 680
 thyroid artery, 590
 transverse ligament of
 scapula, 368
 tympanic artery, 589
 vena cava, 691
 opening into right
 atrium, 556
 vesical artery, 644

Supinator muscle, 498
longus muscle, 496
Supporting cells of Hensen, 1003
of Sertoli, 1166
framework of retina, 963
Supra-auricular point, 261
Supracallosal gyrus, 813
Supraclavicular branches of
brachial plexus, 896
nerves, 893
Supracondylar process, 277*
ridge, lateral, 276
medial, 276
Supraglenoid tuberosity, 269
Suprahyoid aponeurosis, 440
lymph-glands, 714
muscles, 439
triangle, 593
Supramandibular lymph-gland,
714
Supramarginal gyrus, 809
Supramastoid crest, 203
Suprameatal spine, 210, 246
triangle, 203
Supraorbital artery, 598
foramen, 214
margin, 214
nerve, 855
notch, or foramen, 214, 248,
249
vein, 672
Suprarenal arteries, inferior,
640
middle, 639
superior, 641
glands, 1205
accessory, 1206
applied anatomy of, 1207
development of, 101
lymphatic vessels of, 732
structure of, 1206
vessels and nerves of, 1206
impression, 1136
plexus, 939
veins, 703
Suprascapular artery, 610
ligament, 368
nerve, 897
Supraspinal ligament, 352
Supraspinatous fossa, 267
Supraspinatus muscle, 487
Suprasternal space, 436
Supratonsillar fossa, 1072
Supratrochlear foramen, 277
lymph-glands, 718
nerve, 855
Supravesical fovea, 1125
Sural arteries, 662
cutaneous nerve, lateral, 924
medial, 923
nerve, 923
Surface anatomy and surface
markings of—
abdomen, 1233, 1235
regions of, 1235
surface lines of, 1235
accessory nerve, 1224
acoustic meatus, external,
1221
acromioclavicular joint,
1246, 1250
adductor canal, 1261
anal canal, 1242
ankle-joint, 1256, 1260
aorta, abdominal, 1233,
1240
ascending, 1233
aortic arch, 1233

Surface anatomy and surface
markings of (*cont.*)
arteria profunda brachii,
1253
femoris, 1262
auscultation, triangle of,
1229
axillary artery, 1249, 1252
nerve, 1254
back, 1224, 1226
biceps brachii, 1248
bones of cranium, 1209
of lower extremity,
1254
of thorax, 1227, 1229
of upper extremity,
1244
brachial artery, 1249, 1253
plexus, 1224, 1249
brain, 1214
Bryant's triangle, 1260
caecum, 1237
calcaneocuboid joint, 1260
calcaneus, 1255
carpal bones, 1246
caruncula lacrimalis, 1221
central sulcus, 1214
cerebellum, 1214
cerebral hemisphere, 1214
cervical cutaneous nerve,
1224
clavicle, 1244
coeliac artery, 1240
colic flexure, left, 1238
right, 1237
colon, ascending, 1237
descending, 1238
transverse, 1238
common carotid artery,
1211, 1223
left, 1233
iliac artery, 1240
peroneal nerve, 1259,
1263
coracobrachialis, 1248
cranium, 1213
deep peroneal nerve, 1263
deltoidus, 1248
diaphragm, 1230
dorsalis pedis artery, 1259,
1262
duodenum, 1237
ear, 1221
elbow-joint, 1246, 1250
epigastric artery, inferior,
1240
fossa, 1228
external carotid artery,
1211, 1224
main branches of, 1224
iliac artery, 1240
eye, 1220
face, 1216
facial artery, 1224
facial nerve, 1224
femoral artery, 1259, 1262
triangle, 1261
femur, 1254
fibula, 1255
fissures of brain, 1214
of lungs, 1231
fold of buttock, 1254
fold of groin, 1233
frontal air-sinus, 1216
gall-bladder, 1239
gluteal artery, inferior,
1262
superior, 1261

Surface anatomy and surface
markings of (*cont.*)
gluteal fold, 1254
great auricular nerve, 1224
head and neck, 1209
heart, 1231
coronary sulcus, 1232
longitudinal sulcus, an-
terior, 1232
orifices of, 1232
Hesselbach's triangle, 1240
hip-bones, 1254
hip-joint, 1256, 1260
humeral circumflex artery,
1253
humerus, 1245
hyoid bone, 1210
ileocolic junction, 1237
iliac artery, common, 1240
external, 1240
furrow, 1233
infrasternal notch, 1228
inguinal rings and canal,
1235
innominate artery, 1233
vein, left, 1233
right, 1233
internal, pudendal artery,
1262
interphalangeal joints, 1247
intestines, 1237
joints of hand, 1217
of foot, 1260
jugular notch, 1228, 1230
vein, anterior, 1224
external, 1224
internal, 1224
kidneys, 1235, 1239
knee-joint, 1257, 1260
lacrimal puncta, 1221
sac, 1221
large intestine, 1237
larynx, 1212, 1220
lateral cerebral fissure,
1214
plantar artery, 1263
thoracic artery, 1253
ventricle of brain, 1210
latissimus dorsi, 1247, 1251
left common carotid ar-
tery, in thorax, 1233
lesser occipital nerve, 1224
linea nigra, 1233
scapularis, 1233
liver, 1235, 1238
lower extremity, 1254, 1259
lumbar triangle, 1233
lungs, 1231
mammary, 1229
mammary artery, internal,
1233
maxillary artery, external,
1212, 1216
sinus, 1216
medial plantar artery, 1263
median nerve, 1253
medulla spinalis, 1226
mesenteric artery, inferior,
1240
superior, 1241
metacarpal bones, 1246
metacarpophalangeal
joints, 1247
metatarsal bones, 1255
metatarsophalangeal
joints, 1260
midcarpal articulation,
1246

Surface anatomy and surface markings of (*cont.*)

middle meningeal artery, 1216
 mouth, 1217
 mucous sheaths around ankle, 1261
 of wrist and hand, 1252
 muscles of abdomen, 1233
 1235
 of arm, 1247
 of back, 1225
 of buttock, 1257
 of foot, 1258
 of forearm, 1248
 of hand, 1249
 of head and neck, 1210, 1223
 of leg, 1258
 of thigh, 1257
 of thorax, 1229
 of upper extremity, 1247, 1250
 nasal part of pharynx, 1220
 nasolacrimal duct, 1221
 navicular tuberosity, 1255
 neck, 1223
 Nélaton's line, 1200
 nose, 1217
 occipital artery, 1212
 œsophagus, 1231
 palatine arches, 1218
 tonsil, 1219
 palmar or volar arches, 1253
 palpebral fissure, 1220
 pancreas, 1235, 1239
 parotid duct, 1217
 gland, 1217
 patella, 1254
 pectoralis major, 1247, 1251
 minor, 1247, 1252
 pelvis, 1254
 perinaeum, 1241, 1242
 peroneal artery, 1262
 nerves, 1263
 phalanges of foot, 1256
 of hand, 1246
 phrenic nerve, 1224
 plantar arch, 1263
 arteries, 1263
 pleura, 1230
 plica semilunaris, 1221
 popliteal artery, 1259, 1262
 fossa, 1261
 posterior tibial artery, 1259, 1262
 pudendal artery, internal, 1262
 pupil, 1221
 radial artery, 1249, 1253
 nerve, 1254
 radiocarpal joint, 1246, 1250
 radio-ulnar joints, 1246
 radius, 1245
 rectum, 1242
 Reid's base line, 1213
 renal arteries, 1240
 Rolandic fissure, 1215
 sacro-iliac articulation, 1260
 saphenous veins, 1263
 scapula, 1245
 scapular circumflex artery, 1253

Surface anatomy and surface markings of (*cont.*)

sciatic nerve, 1263
 serratus anterior, 1248
 shoulder-joint, 1246
 small intestine, 1237
 space of Traube, 1237
 spinal nerves, 1227
 spleen, 1239
 sternal angle, 1228, 1230
 sternoclavicular joint, 1246
 sternocleidomastoideus, 1211
 sternum, 1227
 stomach, 1236
 striæ gravidarum or albicantes, 1233
 subclavian artery, 1211, 1224, 1249
 subdural and subarachnoid cavities, 1226
 submaxillary gland, 1212
 subscapular artery, 1253
 supraclavicular nerves, 1224
 supraorbital artery, 1212
 Sylvian fissure, 1214
 talonavicular joint, 1260
 talus, 1255
 tarsometatarsal joints, 1260
 tarsus and foot, 1255
 temporal artery, superficial, 1212
 temporomandibular joint, 1210
 tendinous inscriptions of rectus abdominis, 1233
 thoraco-acromial artery, 1253
 thorax, 1227, 1229
 surface lines of, 1230
 tibia, 1255
 tibial artery, anterior, 1259, 1262
 posterior, 1259, 1262
 nerve, 1263
 to toe, 1218
 trachea, 1212, 1231
 transpyloric line, 1235
 transtuberular line, 1235
 transverse cervical artery, 1211
 transverse sinus, 1216
 trapezius, 1211, 1247, 1251
 Traube, space of, 1237
 triangle of auscultation, 1220
 triceps brachii, 1248
 trigeminal nerve, 1217
 tympanic antrum, 1223
 membrane, 1223
 ulna, 1245
 ulnar artery, 1253
 collateral arteries, 1253
 nerve, 1249, 1254
 umbilicus, 1233, 1235
 upper extremity, 1244, 1249
 ureters, 1240
 urogenital organs, female, 1243
 male, 1243
 vena cava, inferior, 1233
 superior, 1233
 vermiform process, 1237
 vertebral column, 1224

Surface anatomy and surface markings of (*cont.*)

volar or palmar arches, 1253
 wrist and hand, 1244
 wrist-joint, 1246, 1250
 xiphoid process, 1228
 Surfaces of bones, 161
 jugular, of temporal bone, 208
 Surgical emphysema, 1043
 neck of humerus, 271
 Suspensory ligament of axilla, 481
 of eye, 972
 of lens, 965
 of ovary, 1179
 of penis, 1174
 Sustentacular fibres of Müller, 963
 Sustentaculum lenis, 1006
 tali, 331, 332
 Sutura, 343
 harmonia, 343
 serrata, 343
 squamosa, 343
 Sutural bones, 224
 applied anatomy of, 224
 ligament, 342
 Suture, coronal, 241, 245
 frontal, 213
 fronto-ethmoidal, 252
 frontomaxillary, 250
 lambdoidal, 195, 212, 241, 248
 metopic, 213
 occipitomastoid, 245
 parietomastoid, 245
 petro-occipital, 254
 petrosphenoidal, 244
 petrosquamous, 204, 206, 209
 sagittal, 212, 241
 spheno-ethmoidal, 252
 sphenofrontal, 245, 252
 sphenoparietal, 245
 spheno-petrosal, 252
 sphenosquamosal, 245
 squamosal, 204, 245
 zygomaticomaxillary, 251
 Sweat-glands, 1014
 development of, 85
 Swellings, arytenoid, 142
 genital, 154
 Sylvian fossa, 99
 veins, deep and superficial, 679
 Sylvius, aqueduct of, 793
 fissure of, 806
 Syme's amputation, 340
 Sympathetic nerves, 928
 connections with spinal nerves, 887, 928
 fibres of spinal nerves, 887
 nervous system, abdominal portion, 935
 cephalic portion, 931
 cervical portion, 932
 pelvic portion, 935
 thoracic portion, 933
 applied anatomy of, 940
 development of, 100
 great plexuses of, 937
 cardiac, 937
 collic, 937
 hypogastric, 940
 pelvic, 940
 solar, 937
 plexuses, 937
 trunks, 930

INDEX

- Symphysis, 344**
 of mandible, 235
 pubis, 390
 sacrococcygeal, 352
Synarthroses, 343
Synchondrosia, 343
 neurocentral, 176
Syncytiotrophoblast, 50, 63
Syndesimology, 342
Syndesmosis, 344
Synechia, 967
Synergic muscles, 424
Synostosis, premature, 25
Synovia, 343
Synovial stratum of articular capsule, 342
Syringomyelia, 759
Systems, Haversian, 19
Systemic circulation, 545
 veins, 671
Systole, atrial, 565
 ventricular, 565

Tabes dorsalis, 838
Tables of the skull, 161, 190
Tactile corpuscles of Golgi and Mazzoni, 1007
 of Grandry, 1006
 of Herbst, 1007
 of Pacini, 1006
 of Ruffini, 1007
 of Wagner and Meissner, 1007
Tactile discs, 1005
Tænia libera, 1122
 mesocolica, 1122
 omentalis, 1122
 pontis, 773
 semicircularis, 823
 thalami, 794
Tænia coli, 1122
 of fourth ventricle, 785
Tail of spermatozoön, 45
Talipes or club foot, 534
Talocalcaneal articulation, 414
 ligament, anterior, 414
 interosseous, 414
 lateral, 414
 medial, 414
 posterior, 414
Talocalcaneonavicular articulation, 415
Talocrural articulation, 411
 applied anatomy of, 413
 movements of, 413
 relations of tendons and vessels to, 412
 surface anatomy of, 1256
Talotibial ligament, anterior, 412
 posterior, 412
Talofibular ligament, anterior, 412
 posterior, 412
Talonavicular ligament, 415
Talus, 328
 ossification of, 338
Tangential fibres of cerebral cortex, 831
Tapetum of chorioid, 957
 of corpus callosum, 815
Tarsal arteries, 606
 bones, 325
 ossification of, 338
 glands, 975
Tarsi of eyelids, 974
Tarsometatarsal articulations, 418

Tarsus, 325
 applied anatomy of, 340
 ossification of, 338
 surface anatomy of, 1255
Taste, nerves of, 943
 organ of, 942
Taste-buds, 942
Tectorial membrane of ductus cochlearis, 1003
 accessory, 1004
Tectospinal fasciculus, 755, 756
Tectum anterius, 75
 posterius, 75
Teeth, 1054
 applied anatomy of, 1064
 bicuspid, 1057
 canine, 1056
 cement or crusta petrosa of, 1059
 chemical composition of, 1059
 crowns of, 1055
 cusps, 1056
 deciduous, 1057
 dentine of, 1058
 development of, 1060, 1063
 enamel of, 1059
 eruption of, 1063
 eye, 1057
 general characteristics of, 1055
 incisors, 1055
 ivory or dentine of, 1058
 milk, 1057
 molar, 1057
 multicuspid, 1057
 necks of, 1055
 permanent, 1055
 premolars, 1057
 pulp-cavity of, 1057
 roots of, 1055
 structure of, 1057
 substantia adamantina of, 1059
 eburnea of, 1058
 ossea of, 1059
 successional permanent, 1063
 superadded permanent, 1063
 wisdom, 1057
Teeth, auditory of Huschke, 1001
Tegmen tympani, 206, 207, 985
Tegmental part of pons, 773
Tegmentum, 789
Tela chorioidea of fourth ventricle, 785
 of third ventricle, 827
Telencephalon, 95, 803
Telophase, 3
Temporal arteries, deep, 589
 middle, 586
 superficial, 586
 bone, 203
 mastoid portion of, 205
 ossification of, 210
 petrous portion of, 206
 pyramid of, 206
 squama of, 203
 structure of, 210
 styloid process of, 210
 tympanic part of, 209
 fascia, 433
 fuses, 245
 gyri, 810
 lines, 203, 211, 214, 245
 lobe, 810
 nerves, deep, 860

Temporal nerves, superficial, 862
 of facial, 870
 operculum, 811
 process of zygomatic bone, 234
 vein, middle, 674
 superficial, 674
Temporalis muscle, 433
Temporary cartilage, 14
Temporomalar nerve, 857
Temporomandibular articulation, 346
 applied anatomy of, 348
 surface anatomy of, 1210
 ligament, 347
Temporomaxillary vein, 674
Tendo Achillis, 530
 calcaneus, 530
 rupture of, 535
 oculi, 429
Tendinous arch of pelvic fascia, 468
 inscriptions of rectus abdominis, 463
Tendinous point, central, of perinæum, 473
Tendon cells, 11
Tendon, central, of diaphragm, 453
 conjoined, of internal oblique and transversus, 403
 of conus arteriosus, 558
 reactions, 838
 structure of, 10
 superior, of Lockwood, 970
 of Zinn, 970
Tendons, 425
 on back of wrist, relations of, 503
Tendril fibres of cerebellum, 782
Tenon, capsule of, 972
Tenosynovitis, 500
Tensor fasciæ latæ muscle, 517
 palati muscle, 1074
 tarsi muscle, 428
 tympani muscle, 990
 semicanal for, 209, 987
 veli palatini muscle, 1074
Tenth thoracic vertebra, 169
 rib, 189
Tentorium cerebelli, 841
Teres major muscle, 488
 minor muscle, 487
Terminal vein, 680
 ventricle, 87, 750
Terminations of motor nerves, 743
 of nerves of general sensations, 1005
Testes, 1164
 appendages of, 1165
 applied anatomy of, 1167
 coni vasculosi of, 1167
 descent of, 151
 development of, 151
 ductuli efferentes of, 1167
 ductus deferens of, 1168
 epididymis, 1164
 gubernaculum testis, 151
 lobules of, 1166
 lymphatic vessels of, 734
 mediastinum testis, 1165
 rete testis, 1167
 septula testis, 1166
 structure of, 1166
 tubuli seminiferi contorti, 1166

- Testes, tubuli recti of, 1167**
 tunica albuginea, 1165
 vaginalis, 1165
 vasculosa, 1166
Testicular arteries, 641
 veins, 702
 applied anatomy of, 703
Thalamencephalon, 793
Thalami, 793
 connexions of, 795
 development of, 94
 massa intermedia, 94, 794
 stalks of, 796
 structure of, 795
 surfaces of, 794, 795
Thalamocortical fibres, 796
Thalamomamillary fasciculus, 796, 799, 825
Thebesius, valve of, 556, 571
Thenar eminence, 500
Thigh, fascia lata of, 516
 muscles of, 515
 superficial fascia of, 515
Third cervical nerve, posterior division of, 888
 cuneiform bone, 324
 ossification of, 338
 metacarpal bone, 295
 metatarsal bone, 337
 occipital nerve, 888
 trochanter, 312
 ventricle of the brain, 802
 choroid plexuses of, 802
Thoracic aorta, 627
 applied anatomy of, 629
 branches of, 629
 peculiarities of, 627
 artery, highest, 615
 lateral, 615
 long, 615
 superior, 615
 axis, 615
 cavity, 550
 curve of vertebral column, 179
 duct, 710
 applied anatomy of, 712
 intercostal nerves, 909
 nerve, long, 897
 applied anatomy of, 906
 twelfth, 910
 nerves, 908
 anterior, 897
 anterior divisions of, 908
 applied anatomy of, 910
 posterior divisions of, 889
 portion of sympathetic, 933
 vertebrae, 167
 viscera lymphatic vessels of, 738
 wall, lymphatic vessels of, 738
Thoracic-abdominal intercostal nerves, 910
Thoracicolumbar group of pre-ganglionic fibres, 928
Thoraco-acromial artery, 615
Thoracodorsal nerve, 899
Thoraco-epigastric vein, 696
Thorax, 190, 550
 boundaries of, 190
 cavity of, 550
 inspection of, 1044
 lower opening of, 190, 550
 lymph-glands of, 735
 lymphatic vessels of, 737
 mechanism of, 363
 muscles of, 450
Thorax, palpation of, 1044
 parts passing through upper opening of, 550
 through lower opening of, 550
 percussion of, 1045
 in rickets, 192
 skeleton of, 190
 subcostal angle, 191
 surface anatomy of, 1227
 markings of, 1229
 upper opening of, 190, 550
Thrombokinas, 29
Thumb, carpometacarpal articulation of, 385
Thymus, 1198
 applied anatomy of, 1200
 development of, 131
 lymphatic vessels of, 739
 structure of, 1200
 vessels and nerves of, 1200
Thyroarytenoideus muscle, 1026
Thyrocerivical trunk, 610
Thyreo-epiglottic ligament, 1018, 1022
Thyroepiglotticus, 1026
Thyroglossal duct, 130, 1065
Thyrohyoideus muscle, 442
 nerve to, 884
Thyroid artery, inferior, 610
 superior, 580
 applied anatomy of, 581
 axis, 610
 cartilage, 1016
 gland, 1195
 applied anatomy of, 1197
 development of, 131
 isthmus of, 1195
 lobes of, 1195
 lymphatic vessels of, 718
 pyramidal lobe of, 1196
 structure of, 1196
 vessels and nerves of, 1197
 notch, superior, 1017
 veins, inferior, 691
 middle, 677
 superior, 677
Thyroidea ima artery, 575
Thyroids, accessory, 1196
Thyrotomy, 1030
Tibia, 318
 applied anatomy of, 324
 condyles of, 318
 intercondyloid eminence of, 318
 ossification of, 321
 spine of, 318
 structure of, 321
 surface anatomy of, 1255
 tuberosity of, 320
Tibial artery, anterior, 664
 applied anatomy of, 665
 branches of, 665
 peculiarities of, 664
 surface marking of, 1262
 posterior, 666
 applied anatomy of, 667
 branches of, 667
 peculiarities of, 667
 surface marking of, 1262
 collateral ligament of knee-joint, 492
 lymph-gland, anterior, 721
 nerve, 922
 anterior, 925
 recurrent artery, anterior, 665
 posterior, 665
Tibial spine, 318
 surfaces of femur, 315
 veins, 698
Tibialis anterior muscle, 528
posterior muscle, 533
Tibiofibular articulation, distal, 410
 proximal, 409
 syndesmosis, 410
Tibiofibular articulations, 409
Tibionavicular ligament, 412
Tinnitus aurium, 875
Tissue, adenoid, 12
 adipose, 9
 areolar, 7
 cancellous, 17
 connective, 7
 lymphoid, 12
 mucous, 12
 muscular, 30
 nervous, 34
 retiform or reticular, 12
 white fibrous, 10
 yellow elastic, 11
Tomes, fibres of, 1059
 granular layer of, 1059
Tongue, 1064
 applied anatomy of, 1071
 development of, 130
 foramen cæcum, 1065
 frenulum of, 1064
 glands of, 1070
 lymphatic vessels of, 718
 mucous membrane of, 1069
 muscles of, 1067
 papillæ of, 1065
 principal lymph-gland of, 718
 septum of, 1067, 1071
 applied anatomy of, 1069
 structure of, 1069
 sulcus terminalis, 1065
 vessels and nerves of, 1071
Tonsil, lingual, 1065, 1072
 pharyngeal, 1077
Tonsillæ of cerebellum, 778
Tonsillar artery, 584
 nerves from glossopharyngeal, 876
 sinus, 1072
Tonsils, palatine, 1072
 applied anatomy of, 1073
 development of, 131
 lymphatic vessels of, 717
 structure of, 1073
 vessels and nerves of, 1073
Torcular Herophili, 194, 683
Torticollis or wryneck, 439, 882
Torus of auditory tube, 988, 1076
 uretericus, 1158
 uterinus, 1090
Trabeculæ carnae of left ventricle, 561
 of right ventricle, 559
 cranii, 74
 of penis, 1175
 of spleen, 1202
Trachea, 1027
 applied anatomy of, 1030
 relations of, 1027
 structure of, 1029
 vessels and nerves of, 1030
Tracheal branches of inferior thyroid artery, 610
 lymph-glands, 737
Tracheal tugging, 674
Trachealis muscle, 1030

INDEX

- Trachelomastoidous muscle,** 447
Tracheobronchial lymph-glands, 737
 applied anatomy of, 737
Tracheotomy, 1031
Trachoma glands, 976
Tract or tracts—
 anterior basis bundle, 755
 anterior proper, 755
 of Burdach, 756
 cerebellospinal of Löwenthal, 755
 cerebrospinal, anterior, 754
 lateral, 755
 comma-shaped, 758
 cornucommissural, 757
 crossed pyramidal, 755
 direct cerebellar of Flechsig, 756
 pyramidal, 754
 dorsal peripheral band, 758
 of Goll, 756
 of Gowers, 756
 iliotibial, 516
 lateral basis bundle, 756
 lateral proper, 756
 of Lissauer, 756
 motor, 835
 olfactory, 812
 olivospinal (Helweg), 756
 optic, 802
 oval area of Flechsig, 758
 rubrospinal of Monakow, 755
 secondary sensory, 756
 sensory, 836
 spinocerebellar, anterior, 756
 spinotroctal, 756
 spinothalamic, 756
 tectospinal, 755, 756
 triangular strand, 758
 vestibulospinal, 755
Traction epiphyses, 24
Tractus peduncularis transversus, 788*
 solitarius, 91
 spiralis foraminosus, 207, 995, 1004
Tragicus muscle, 981
Tragus, 979
Transitional epithelium, 7
Transpyloric plane, 1084
Transversa colli artery, 611
Transversalis cervicis muscle, 447
 fascia, 465
Transverso acetabular ligament, 396
 carpal ligament, 500
 cervical artery, 611
 ascending branch, 611
 descending branch, 611
 nerve, 893
 colon, 1118
 crural ligament, 535
 diameter of pelvis, 305
 facial artery, 586
 vein, 674
 fasciculi, superficial of hand, 505
 fibres of cerebral hemispheres, 828
 fissure of brain, 827
 of liver, 1135
 folds of rectum, 1120
 humeral ligament, 370
Transverse ligament of atlas, 355
 crus inferius, 355
 crus superius, 355
 inferior, of distal tibio-fibular articulation, 410
 of knee, 405
 metacarpal, 386
 metatarsal, 410
 of pelvis, 476
 ligaments of scapula, 368, 369
 mesocolon, 1096
 occipital sulcus, 809
 processes of a vertebra, 162
 scapular artery, 610
 sinus of pericardium, 552
 sinuses of dura mater, 681
 sulci, 194
 temporal gyri, 810
Transversus abdominis muscle, 462
 auriculæ muscle, 981
 linguæ, 1069
 menti muscle, 431
 nuchæ muscle, 427
 pedis muscle, 540
 perinæi profundus muscle, in female, 477
 in male, 476
 perinæi superficialis muscle, in female, 476
 in male, 473
 thoracis muscle, 451
Trapezium, 292
Trapezius muscle, 478
Trapezoid, 292
 body, 773
 ligament, 367
 nucleus, 773
 ridge, 271
Treves, bloodless fold of, 1098
Triangle of auscultation, 480, 1229
 Bryant's 1260
 carotid, 592
 inferior, 592
 deltoideopectoral, 483
 digastric, 592
 femoral, 654
 of Hesselbach, 1126
 lumbar, 480
 muscular, 592
 of neck, anterior, 591
 posterior, 593
 occipital, 593
 of Petit, 480
 Scarpa's, 654
 subclavian, 593
 submaxillary, 592
 suboccipital, 449
 suprahyoid, 593
 suprapectoral, 203, 248
Triangular fascia, 460
 ligament, 475
 deep layer of, 476
 superficial layer of, 475
 left, of liver, 1087, 1137
 right, of liver, 1087, 1137
 strand, 758
Triangularis muscle, 430
sterni muscle, 451
Triceps brachii muscle, 490
 applied anatomy of, 491
 sural muscle, 240
Trichterbrust, 192
Tricuspid valve, 558
Trigeminal impression,* 207
Trigeminal nerve, 853
 applied anatomy of, 863
 surface marking of, 1217
 reflexes, 864
Trigone, olfactory, 812
Trigonum collaterale, 819
 habenulæ, 797
 hypoglossi, 768, 786, 882
 vagi, 768
 vesicæ, 1158
Trigonum fibrosum of heart, 562
Triquetral bone, 291
 ossification of, 296
Trochanter, greater, 311
 lesser, 312
 third, 312
Trochanteric fossa, 311
Trochlea of humerus, 277
 of talus, 329
Trochlear fovea, 215, 249
 nerve, 862
 applied anatomy of, 853
 process of calcaneus, 332
 spine, 215, 249
Trochoid articulation, 344
Trolard, great anastomotic vein of, 679
Troeltsch, recesses of, 991
Trophoblast, 490
Tropical abscess of liver, 1142
True pelvis, 305
 ribs, 185
 vertebræ, 161
 vocal cords, 1023
Truncus arteriosus, 113
Trunk, arteries of, 627
 fasciæ and muscles of, 444
Trunks, sympathetic, 689
Tubal pregnancy, 47
Tube, auditory or Eustachian, 988
 pharyngeal ostium of, 1076
 tonsil of, 988
 digestive, 1045
 laryngotracheal, 142
 neural, 53
Tube-tonsil, 988
Tuber cinereum, 799
 omentale of liver, 1136
 of pancreas, 1130
 vermis of cerebellum, 778
Tubercle, adductor, 312
 articular, of temporal bone, 203, 243
 auricular, of Darwin, 979
 Chassaignac's, 160
 cloacal, 154
 conoid, 271
 cuneate, 764
 cuneiform, 1023
 deltoid, 271
 of epiglottis, 1019
 of femur, 312
 genital, 161
 of humerus, greater, 274
 lesser, 274
 interosseous, 557
 lacrimal, 228
 of lower, 557
 mental, 235
 obturator, anterior, 303
 posterior, 301, 303
 peroneal, 332
 pharyngeal, 196, 243
 postglenoid, 204
 radial, 302

Tubercle of rib, 187
 ligament of, 360
 of Rolando, 764
 scalene, 188
 Tuberculum anterius, 164
 caroticum, 164
 cinereum, 764
 impar, 130
 jugulare, 196
 posterius, 164
 sellae, 197, 252
 Tuberosity, calcaneal, 332
 coracoid, 271
 costal, 272
 of cuboid, 335
 deltoid, 276
 frontal, 213
 of fifth metatarsal bone, 337
 gluteal, 312
 iliac, 300
 infraglenoid, 268
 of ischium, 302
 maxillary, 224
 of navicular bone, 333
 of palatine bone, 232
 parietal, 211
 radial, 282
 sacral, 173
 supraglenoid, 268
 of tibia, 326
 of ulna, 284
 Tubes, uterine or Fallopian, 1182
 Tubotympanic recess, 108
 Tubules, renal, 1147
 Wolffian, 446
 Tubuli lactiferi, 1194
 seminiferi contorti, 1166
 Tunic, dartos, 1171
 Tunica adventitia, 546
 albuginea of ovary, 1180
 of testis, 1165
 elastica externa, 546
 intima, 546
 media, 546
 vaginalis, 152, 1165
 vasculosa of testis, 1166
 Tunics of eye, 951
 Tunnel of Corti, 1001
 Turner, intraparietal sulcus of, 809
 Twelfth thoracic vertebra, 169
 rib, 189
 Tympanic antrum, 206, 968
 entrance to, 982
 surface marking of, 1223
 artery, anterior, 587
 inferior, 581
 canaliculus, inferior, 208, 244
 cavity, 984
 applied anatomy of, 992
 attic or epitympanic recess of, 984
 auditory (Eustachian) tube, 988
 carotid or anterior wall of, 987
 development of, 107
 jugular wall or floor of, 985
 labyrinthine or medial wall of, 986
 mastoid or posterior wall of, 986
 membranous or lateral wall of, 985
 mucous membrane of, 991

Tympanic cavity, muscles of, 900
 ossicles of, 988
 development of, 108
 movements of, 990
 tegmental wall or roof of, 985
 vessels and nerves of, 991
 cresta, superior and inferior, 210*
 lip, 1001
 membrane, 985
 pars flaccida, 986
 pars tensa, 986
 structure of, 986
 vessels and nerves of, 988
 secondary, 986, 996
 nerve (Jacobson's), 876, 991
 part of temporal bone, 209
 plexus, 876, 991
 ring, 210
 sulcus, 209, 982, 985
 Tympanohyal part of styloid process, 210
 Typical vertebra, 161
 Ulna, 283
 applied anatomy of, 286
 coronoid process of, 284
 olecranon of, 284
 ossification of, 286
 radial notch of, 285
 semilunar notch of, 284
 sigmoid cavities of, 284, 285
 structure of, 286
 styloid process of, 286
 surface anatomy of, 1245
 tuberosity of, 284
 Ulnar artery, 623
 applied anatomy of, 624
 branches of, 625
 peculiarities of, 624
 recurrent anterior, 625
 posterior, 625
 surface marking of, 1253
 collateral artery, inferior, 619
 superior, 619
 collateral nerve, 904
 collateral ligament of elbow-joint, 374
 collateral ligament of wrist-joint, 381
 nerve, 903
 applied anatomy of, 907
 notch of radius, 282
 Ultramembranous bodies, 132
 Umbilical arteries in fetus, 66, 506, 644
 cord, 62
 folds, 1125, 1157
 fossa of liver, 1134
 ligament, lateral, 644
 middle, 1157
 region, 1084
 veins, 63, 113, 569
 vesicle, 56
 Umbilicus, 465
 Umbo of membrana tympani, 986
 Unciform bone, 293
 Uncinate fasciculus, 828
 process of ethmoidal bone, 210
 of head of pancreas, 1128
 Uncrossed lateral cerebellar fibres, 756
 Uncus, 812
 Ungual phalanges of foot, 337
 of hand, 296

Unstriated muscle, 32
 Upper extremity, arteries of, 602
 articulations of, 365
 bones of, 266
 fasciae and muscles of, 478
 lymph-glands of, 718
 lymphatic vessels of, 721
 surface markings of, 1249
 veins of, 689
 motor neurons, 836
 Urachus, 153, 1164
 Ureter, 1152
 abdominal part of, 1152
 applied anatomy of, 1153
 arteries of, 1153
 lymphatic vessels of, 733
 muscles of, 1159
 nerves of, 1153
 orifices of, 1158
 pelvic part of, 1152
 structure of, 1153
 Urethra, development of, 154
 female, 1163
 male, 1160
 applied anatomy of, 1162
 cavernous portion of, 1162
 crest or verumontanum of, 1161
 lymphatic vessels of, 734
 membranous portion of, 1161
 prostatic portion of, 1161
 utricle, 1161
 structure of, 1162
 Urethral artery, 647
 bulb, 1173
 artery of, 647
 crest, in female, 1163
 in male, 1161
 glands, 1162
 orifice, external, 1162, 1192
 internal, 1158
 plate, 1164
 Urinary bladder, 1154
 applied anatomy of, 1159
 development of, 153
 lymphatic vessels of, 733
 organs, 1143
 development of, 145
 lymphatic vessels of, 732
 Urogenital apparatus, 1143
 diaphragm, 475
 inferior fascia of, 475
 superior fascia of, 476
 fold, 147
 ostium, primitive, 155
 region, muscles of, in female, 476
 in male, 473
 sinus, 153
 Urorectal septum, 139
 Uterine artery, 645
 cervical ganglion, 940
 glands, 1189
 plexus of nerves, 940
 plexuses of veins, 701
 tube, 1182
 abdominal ostium of, 1182
 ampulla of, 1182
 appendices vesiculosae of, 1182
 applied anatomy of, 1183
 development of, 149
 fimbriae of, 1182
 infundibulum of, 1182
 isthmus of, 1182
 lymphatic vessels of, 735

tube, pars uterina tube, 1182
 structure of, 1182
 lateral ligaments, 1186
 as, 1183
 applied anatomy of, 1189
 of, 1185
 of, 1185
 of, 1149
 693
 1233
 85
 1187
 1187
 of, 1189
 or prostatic
 ie, prostatic, 1161
 vestibule, 997
 structure of, 998
 959
 of cerebellum, 778
 atine, 1048
 ace, 1158
 aa, 1190
 unns of, 1190
 nices of, 1190
 aphatic vessels of, 735
 acture of, 1190
 tibule of, 1192
 a processu styloidei, 208,
 09
 as mucose, 343
 345
 arch
 po
 artery
 body,
 canal,
 column bone,
 appl
 artic
 cartil, 881
 curves, 865
 develop
 -ature
 k; phosis
 laminect
 lateral cur
 181
 lordosis
 memb
 ossific
 surfac
 veins, 557
 fram
 nov
 of the basili
 trispid, 5, 558, 671
 de Vleussens
 alves, anal, 1
 aortic semilunar, 561
 of heart, actions of
 development of,

Valves of Houston, 1120
 of lymphatics, 707
 pulmonary semilunar, 559
 right and left venous, 115
 of veins, 550
 Valvula conniventes, 1110
 Varicocele, 703
 Varicosity of saphenous veins,
 697
 Vas aberrans of Haller, 1169
 deferens, 1168
 spirale, 1001
 Vasa aberrantia, from brachial
 artery, 618
 brevia of stomach, 635
 intestini tenuis, 636
 vasorum of arteries, 547
 of veins, 550
 Vascular area of yolk-sac, 100
 capsule of lens, 104
 system, changes in, at birth,
 568
 development of, 109
 peculiarities in foetus, 566
 tunic of bulb of eye, 955
 Vasomotor nerve-fibres, 742
 Vastus intermedius muscle,
 519
 lateralis muscle, 518
 medialis muscle, 518
 Vater, ampulla of, 1141
 Vein or veins—
 of abdomen, 698,
 anastomotic, of Labbé, 679
 of Trolard, 679
 angular, 673
 anterior cardiac, 672
 vertebral, 678
 ascending lumbar, 702
 auditory, internal, 1004
 auricular, posterior, 674
 axillary, 690
 applied anatomy of, 690
 azygos, 693
 basal, 679
 basilic, 688
 basivertebral, 694
 brachial, 690
 of the brain, 679
 bronchial, 694, 1043
 cardiac, 672
 cardinal, anterior, 123
 posterior, 123
 cava, inferior, 701
 applied anatomy of, 702
 superior, 691
 applied anatomy of, 693
 cephalic, 687
 accessory, 688
 cerebellar, 680
 cerebral, 679, 680
 anastomotic of Labbé, 679
 of Trolard, 679
 anterior, 679
 basal, 679
 chorioid, 680
 ciliary, 966
 deep middle, 679
 external, 680
 of Galen, 680
 great, 680
 inferior, 679
 inferior, 679
 internal, 679
 middle, 679
 superior, 679
 Sylvian, deep, 679
 superficial, 679

Vein or veins (*cont.*)
 cerebral, terminal, 680
 cervical, deep, 678
 chorioid, 680
 coats of, 549
 comitans of hypoglossal
 nerve, 677
 common facial, 673
 iliac, 701
 vitello-umbilical, 113
 condyloid, 687
 coronary sinus, 671
 of stomach, 706
 cystic, 706
 deep, 670
 facial, 674
 of forearm, 690
 of hand, 690
 of lower extremity, 698
 of upper extremity, 689
 development of, 122
 digital, of foot, 695
 of hand, 687
 diploic, 678
 dorsal digital, 687, 695
 metacarpal, 687
 metatarsal, 687
 plantar, 698
 of penis, 701
 venous arch, 687
 network, 687
 emissary, 686
 applied anatomy of, 687
 epigastric, inferior, 692
 superficial, 696
 facial, anterior, 673
 applied anatomy, 1154
 common, 673
 deep, 674
 posterior, 674
 transverse, 674
 femoral, 698
 frontal, 672
 of Galeo, 680
 gastric, right, 706
 short, 705
 gastro-epiploic, left, 705
 right, 706
 gluteal, 700
 great cardiac, 672
 hæmorrhoidal, inferior, 700
 middle, 700
 plexus, 700
 applied anatomy of, 701
 superior, 705
 of hand, 687, 690
 of head and neck, 672
 of heart, 671
 hemiazygos, 693
 accessory, 693
 hepatic, 703
 histology of, 549
 hypogastric, 690
 iliac, circumflex, deep, 699
 superficial, 696
 com, 70
 external, 698
 internal, 699
 inferior cava, 701
 innominate, 691
 intercapitular, 687, 695, 698
 intercostal, 693
 interlobular, of kidney, 1150
 of liver, 1139
 internal mammary, 691
 intervertebral, 695
 intralobular, of liver, 703,
 1139

articular septum, muscular, 565
 atole, 565
 articularis muscle, 1026
 cinctus, 1098
 ventricle of, 824
 articular fossa, 194
 uniform process or appendix, 1116
 lymphatic vessels of, 731
 structure of, 1117
 axis of cerebellum, inferior, 775, 787
 superior, 775, 776
 foramina, 85
 articular, antecubital, 167*
 eleventh thoracic, 169
 fifth lumbar, 170
 first cervical, 164
 first thoracic, 168
 ninth thoracic, 169
 prominens, 166
 ossification of, 178
 second cervical, 165
 seventh cervical, 166
 tenth thoracic, 169
 twelfth thoracic, 169
 Vertebra, 161
 articular processes of, 162
 bodies of, 161
 cervical, 162
 cervicales, 162
 coccygeal, 178
 false or fixed, 161
 general characteristics of, 161
 laminae of, 162
 ligaments of, 349
 lumbales, 169
 lumbar, 169
 ossification of, 176
 pedicles of, 161
 sacral, 171
 spinous processes of, 162
 structure of, 162
 thoracales, 167
 thoracic, 167
 transverse processes of, 162
 true or movable, 161
 Vertebral arch, 161
 arches, articulations of, 351
 pedicles or roots of, 161
 artery, 606
 body, 161
 canal, 181
 column, 161, 179
 applied anatomy of, 181
 articulations of, 348
 cartilaginous, 70
 curves of, 179
 development of, 69
 fracture-dislocation of, 181
 kyphosis of, 181
 laminectomy, 182
 lateral curvature of, 179, 181
 lordosis of, 181
 membranous, 69
 ossification of, 176
 surface anatomy of, 1224
 veins of, 694
 foramen, 161
 foramen, 180
 muscles, anterior, 442
 lateral, 444
 notches, 162
 ribs, 186, 365
 vein, 678

Vertebral column, 161, 179
 venous plexuses, 694
 Vertebrochondral ribs, 186, 364
 Vertebrocostal ribs, 364
 Vertical circumference of skull, 261
 index of skull, 261
 part of palatine bone, 231
 Verticalis linguae, 1069
 Verumontanum, 1181
 Vesica folles, 1140
 urinaria, 1154
 Vesical artery, inferior, 645
 superior, 644
 layer of pelvic fascia, 469
 plexus of nerves, 940
 of veins, 700
 Vesicle, auditory, 106
 germinal, 42
 lens, 102
 umbilical, 56
 Vesicles, cerebral, 53, 90
 optic, 94, 102
 Vesico-uterine excavation, 1087, 1184
 Vesiculae seminales, 1169
 applied anatomy of, 1170
 lymphatic vessels of, 735
 structure of, 1170
 vessels and nerves of, 1170
 Vesicular ovarian follicles, 1180
 Vestibular arteries, 1004
 bulb, 1192
 fissure, 996
 ganglion, 1004
 glands, greater, 153, 1192
 lip, 1001
 membrane of Reissner, 999
 nerve, 872, 1004
 nuclei of, 775, 873
 Vestibule, aortic, 561
 of bronchiole, 1042
 of internal ear, 993
 of larynx, 1022
 of mouth, 1046
 of nasal cavity, 945
 of omental bursa, 1092
 of vagina, 1192
 Vestibulospinal tract, 755
 Vestigial fold of pericardium (Marshall), 126, 552
 Vicq d'Azyr, bundle of, 799, 825
 Vidian artery, 590, 596
 nerve, 858
 Viessens, valve of, 780
 Villi of chorion, 65
 of intestine, 1111
 Vincula brevia, 494
 longa, 494
 tendinea, 494, 539
 Visceral arches, 77
 lymph-glands of abdomen and pelvis, 726
 of thorax, 736
 veins, 122
 Visual centres, higher or cortical, 802, 850
 lower, 797, 800, 850
 purple, 14, 960
 Visuopsychic area, 832
 Visuosensory area, 832
 Vitelline circulation, 57
 duct, 56, 57, 133
 fluid, 57
 membrane, 447
 veins, 112, 122
 Vitello-umbilical vein, common, 113

Vitreous body of the eye, 964
 development of, 106
 Vocal cords, false, 1023
 true, 1023
 folds, 1023
 fremitus, 1045
 ligaments, 1023
 process of arytenoid cartilage, 1018
 Vocalis muscle, 1026
 Volar antibrachial muscles, 491
 arch, deep, 623
 superficial, 627
 applied anatomy of, 627
 surface markings of, 1253
 artery, superficial, 622
 branch, deep, of ulnar artery, 626
 of ulnar nerve, 904
 carpal branch of radial artery, 622
 of ulnar artery, 625
 carpal ligament, 500
 network, 622, 625
 digital arteries, common, 627
 proper, 627
 nerves, 903, 904
 veins, 687, 690
 interosseous artery, 627
 nerve, 901
 ligaments, accessory, 627
 metacarpal arteries, 627
 veins, 690
 radiocarpal ligament, 381
 venous arches, 690
 Volaris indicis radialis artery, 623
 Voluntary muscle, 30
 Volvulus, 1124
 Vomer, 222
 ossification of, 222
 Vomeroneasal cartilage, 223, 947
 organs, 82, 947
 Vulva, 1191
 of third ventricle, 803
 Wagner and Meissner, corpuscles of, 1007
 Wallerian degeneration, 40, 754
 Wandering cells, 9
 Weight of brain, 834
 Wens, 428
 Wharton, duct of, 1052
 jelly of, 12, 62
 White commissure of medulla spinalis, 747
 fibres of arcolar tissue, 7
 fibrocartilage, 16
 fibrous tissue, 10
 line of pelvic fascia, 468
 nerve-fibres, 37
 nerve-substance of cerebellum, 778
 of cerebral hemispheres, 827
 of medulla spinalis, 753
 substance of pons, 38, 39
 Whitlow, 505
 Width of face, 261
 Willis, arterial circle of, 601
 cords of, 680
 Windpipe, 1027
 Winged scapula, 271, 435
 Wings of sphenoid, great, 199
 small, 200
 Winslow, foramen of, 136, 1091

